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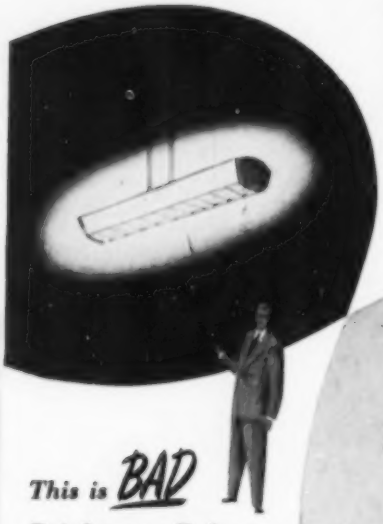

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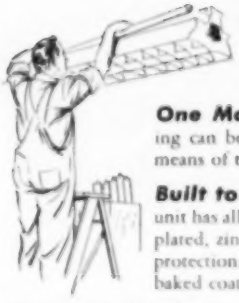

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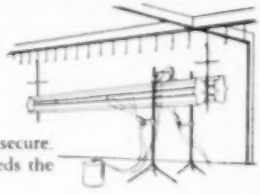

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ILLUMINATING ENGINEERING

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A New Scale of Relative Footcandles for the Luckiesh-Moss Visibility Meter

By MATTHEW LUCKIESH, S. K. GUTH and A. A. EASTMAN

VARIOUS relationships may be obtained to correlate the fundamental factors of size, brightness, brightness-contrast and time which combine to determine the degree of visibility of any object or visual task. These relationships may be used to establish a scale of footcandle-levels for various tasks which will provide a given degree of supra-threshold visibility. However, the direct application of these correlations requires a detailed analysis of each visual task to determine, for example, the critical size that must be discriminated and the contrast between the object and its immediate background. This is difficult and often impossible to accomplish. Therefore, it is highly desirable to develop a means by which any visual task, regardless of its complexity, may be evaluated and its degree of supra-threshold visibility with a specific illumination may be appraised. Furthermore, such a method should make it possible to determine the footcandle-level necessary to raise the visibility of the task to a desired supra-threshold value. A device which permits one to achieve these objectives is the Luckiesh-Moss Visibility Meter.[1]

The relative visibility scale of the meter is calibrated in terms of the sizes of a series of standard parallel-bar test-objects illuminated with 10 footcandles and viewed by an observer with average normal vision. In effect it is a transfer medium by which different visual tasks can be rated in terms of the visibility-levels of the standard series of objects. Units of measurement, of necessity, are defined by arbitrary standards that are relatively simple and readily reproduced. This scale of relative visibility has been applied effectively in the study of the visibility-levels of many diversified tasks.

The present scale of relative footcandles of the meter was designed to enable the user to determine the footcandles required to raise a task to any desirable and attainable visibility-level. The scale has proved somewhat difficult to apply and has been superseded by a family of curves relating visibility and footcandles.[2] While this was a practical step forward in making the visibility meter a more useful instrument, it still left something to be desired. A direct-reading scale that is based upon footcandle values would be more practicable in lighting practice. Fry[3] has prepared an analysis of the Luckiesh-Moss Visibility Meter and has demonstrated how such a scale can be developed from the characteristics of the photographic gradients. The present paper presents the development of a scale of relative footcandles that is based upon the calibration data of the visibility meter and which can be used with simple calculations without requiring reference to charts and tables.

The new scale of relative footcandles is based upon the premise that the ratio of the footcandles for a specific visibility-level to the footcandles for threshold visibility will always be the same regardless of the task. The *actual* footcandle values for the threshold and the specific supra-threshold visibility-level are different for different tasks, but the footcandle-ratios are constant. In other words, each visibility-level can be specified by a corresponding footcandle-ratio or relative footcandle value.

The development of the new scale is illustrated by Fig. 1. The curve represents the relationship between visibility-level and footcandle-level for well-printed 8-point type when viewed by observers possessing average normal vision. The footcandle-level required by these observers to be able to barely read the specific 8-point type (printed with black ink on white paper) when viewing it directly without the visibility meter is 0.01 footcandle. In other words, 0.01 footcandle is the absolute threshold footcandle-level for this particular visual task. The inner left-hand scale of Fig. 1 indicates the actual footcandle-levels required for the various visibility-levels. The relative footcandles with respect to the threshold footcandle-level are indicated by the outer left-hand scale on which the threshold value has been given a value of unity. Thus, any supra-threshold value may be expressed as being a specific multiple of the threshold footcandle-level. For example, the footcandle-level necessary for a visibility-level of 3 is 5.9 which corresponds to a relative value of 590. In other words, a supra-threshold visibility-level of 3 requires an illumination that is 590 times the threshold illumination.

An alternate method of expressing supra-threshold

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footcandle-levels is represented by the right-hand ordinate of Fig. 1. This scale represents equal logarithmic steps above the threshold footcandle-level, each unit corresponding to one log-cycle of illumination. Thus 5.9 footcandles is equivalent to 2.77 log-units above the threshold footcandle-level. This may be stated as $10^{2.77}$ or 590 times the threshold footcandle-level.

Relative footcandles and log-units above the threshold illumination for various visibility-levels are tabulated in Table I.

The significance of Fig. 1 and Table I and their application to objects of other sizes is illustrated by the data of Table II. These data have been obtained from the relationships between footcandle-level and visibility-level for a series of black parallel-bar test-

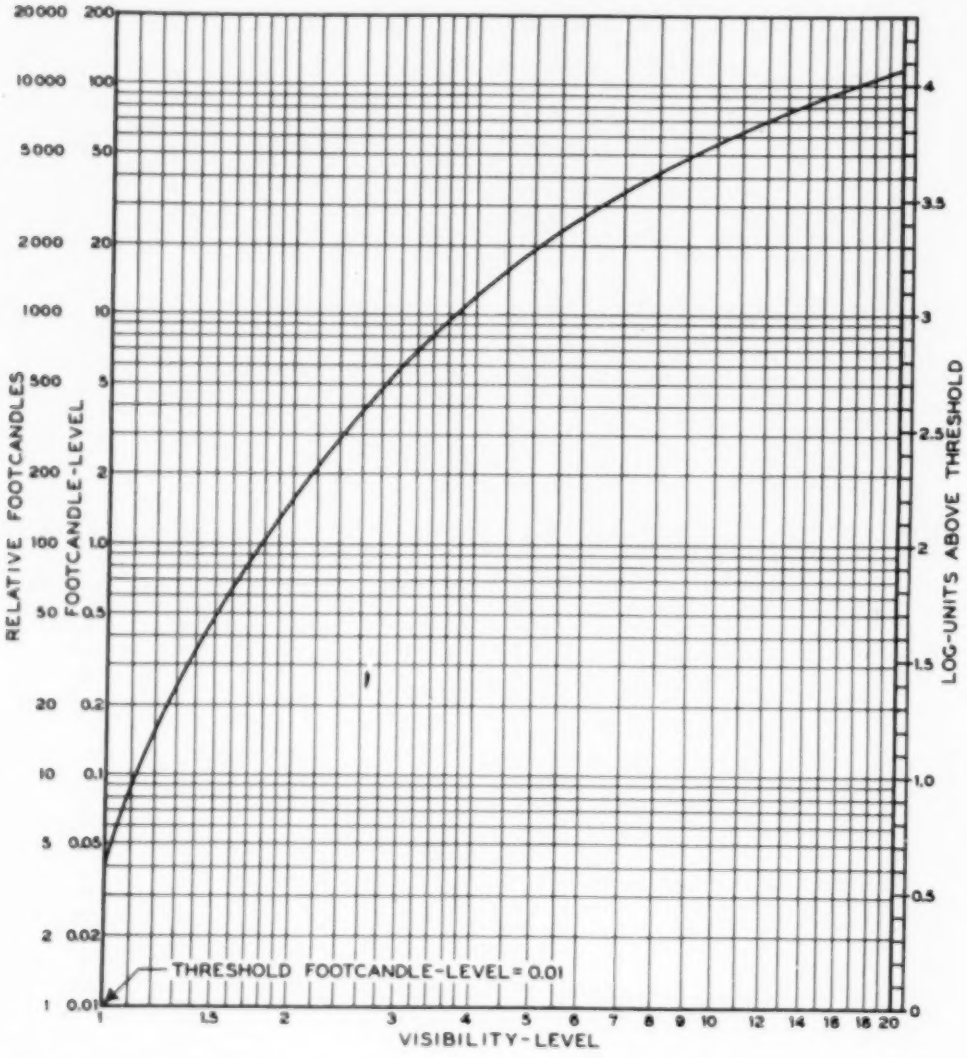

Figure 1. The relationship between visibility-level and footcandle-level for 8-point type. The values indicated by the outer left-hand scale are relative footcandles above the threshold footcandle-level. The right-hand ordinate represents equal logarithmic steps above the threshold footcandle-level.

TABLE I.—Relative Footcandles for Various Visibility-Levels and the Number of Log-Units Each Footcandle-Level Is Above the Threshold

Visibility Level	Relative Footcandles	Log-Units Above Threshold
Threshold	1	0
1.0	4	0.60
1.1	9	0.95
1.2	15	1.16
1.3	23	1.36
1.4	34	1.53
1.5	47	1.67
1.6	63	1.80
1.7	82	1.91
1.8	103	2.01
1.9	128	2.11
2.0	155	2.19
2.2	217	2.34
2.4	290	2.46
2.6	380	2.58
2.8	480	2.68
3.0	590	2.77
3.2	710	2.85
3.4	825	2.92
3.6	940	2.97
3.8	1075	3.03
4.0	1210	3.08
4.5	1560	3.19
5.0	1920	3.28
5.5	2300	3.36
6.0	2880	3.43
7.0	3480	3.54
8.0	4220	3.62
9.0	5000	3.70
10.0	5700	3.76
11.0	6300	3.80
12.0	6970	3.84
13.0	7600	3.88
14.0	8200	3.91
15.0	8800	3.94
16.0	9400	3.97
17.0	10000	4.00
18.0	10600	4.03
19.0	11100	4.05
20.0	11700	4.07

objects ranging in visual sizes from one to 20 minutes when viewed against a white background. They represent the logarithmic differences between the footcandle-levels required for successive visibility-levels of a specific test-object. For example, a 2-minute test-object requires 10 and 21 footcandles for visibility-levels of 2 and 2.5, respectively. The difference between the logarithms of these footcandle-levels is 0.32. Table II illustrates that for a specific difference of visibility-level, the log-unit difference between the footcandle-levels required for these visibility-levels is constant for a wide range in the sizes of objects. This is evidenced by the small variation in log-units across any line of Table II.

A visibility-level of one indicates that an object is just barely visible when viewed through the clearest portion of the gradients of the Luckish-Moss Visibility Meter. Since there is some absorption by this part of the gradient, the absolute threshold of visibility of the task when it is viewed without the visibility meter will be obtained with a lower footcandle-level. From available data it has been determined that the threshold illumination (footcandles) is approximately 0.64 log-unit below the illumination required for a visibility-level of one. The values in the last column of Table II have been obtained by successive addition of the average values plus 0.64 and result in a series of log-units of illumination above the threshold footcandle-level for objects of various sizes. Comparing these values with those in the third column of Table I, it is evident that the latter may be used not only for the 8-point type, but for other visual objects and tasks.

The effect of various contrasts is illustrated by Table III, in which are summarized the logarithmic differences in footcandles-levels required for visibility-levels of 7 and 8 for objects varying in size

TABLE II.—Differences in Log-Units of Footcandles Above Threshold Between Successive Steps in Visibility-Levels for Various Sizes of Black Test-Objects Viewed Against a White Background

Visibility Level	Visual Size of Objects, Minutes											Average Difference	Log-units above Threshold
	1	1.5	2	2.5	3	4	5	7	10	15	20		
1													0.64
	1.68	1.60	—	—	—	—	—	—	—	—	—	1.64	
1.5													1.68
	0.56	0.52	0.54	0.52	—	—	—	—	—	—	—	0.52	
2													2.20
	0.34	0.34	0.32	0.34	0.31	0.33	—	—	—	—	—	0.33	
2.5													2.53
	—	0.24	0.25	0.24	0.28	0.24	0.23	—	—	—	—	0.24	
3													2.77
	—	0.31	0.32	0.31	0.30	0.31	0.33	0.31	0.30	—	—	0.31	
4													3.08
	—	0.20	0.20	0.19	0.20	0.22	0.21	0.20	0.20	0.20	0.20	0.20	
5													3.28
	—	0.14	0.15	0.16	0.14	0.14	0.15	0.14	0.15	0.15	0.15	0.15	
6													3.43
	—	0.12	0.11	0.12	0.11	0.12	0.10	0.11	0.11	0.10	0.12	0.11	
7													3.54
	—	0.09	0.08	0.08	0.09	0.08	0.08	0.09	0.08	0.09	0.08	0.08	
8													3.62
	—	—	0.12	0.12	0.13	0.12	0.14	0.12	0.12	0.12	0.13	0.12	
10													3.74
	—	—	0.10	0.10	0.09	0.09	0.08	0.10	0.10	0.10	0.09	0.09	
12													3.83
	—	—	0.13	0.13	0.12	0.12	0.14	0.13	0.13	0.14	0.14	0.13	
16													3.96
	—	—	0.09	0.09	0.11	0.11	0.10	0.09	0.09	0.08	0.09	0.09	
20													4.05

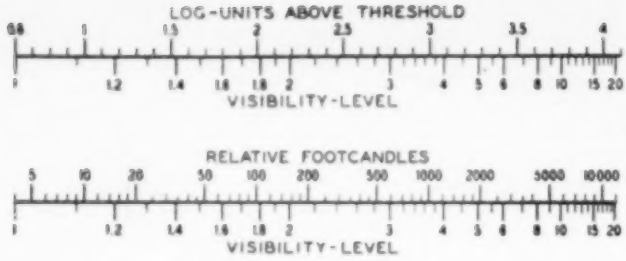

Figure 2. Scales for converting visibility-levels to relative footcandles and log-units above the threshold footcandle-level.

from one to 20 minutes and also varying in contrast from 5 to 95 per cent. The average log-difference is 0.08 with a variation from 0.07 to 0.10. There is no indication of a systematic variation due either to size or contrast. Similarly consistent data were obtained for other visibility-levels.

From Tables II and III it is evident that the values in Table I are valid for a wide range of visual objects or tasks of different size and contrast. The relationship between visibility and relative footcandles in Table I (or corresponding scales on the Luckiesh-Moss Visibility Meter) makes it possible to evaluate in terms of illumination (footcandles) the supra-threshold visibility of an extensive variety of visual tasks. Thus, the footcandle-level for a specific supra-threshold visibility-level, such as a visibility-level of 9, can be defined as being 5000 times the threshold footcandle-level or as being 3.7 log-units above the threshold-level. Furthermore, such a table or scale permits ready calculation of footcandle-levels necessary to obtain desired visibility-levels.

The determination of the footcandle-level required to obtain a desired visibility-level for a given visual object or task becomes a simple matter of determining how much an existing footcandle-level is above the threshold, and then computing the factor by which this existing footcandle-level must be increased in order to raise the object or task to the desired supra-threshold visibility-level. For example, suppose that the observed visibility-level of a specific task when illuminated with 10 footcandles is 1.9. From Table I it is found that this visibility-level corresponds to a relative footcandle-level of 128 or to 2.11 log-units above the threshold. It is desired to determine the footcandle-level that will raise the visibility-level of the task to 9, which corresponds to a relative footcandle-level of 5000, or 3.7 log-units of illumination above threshold. The ratio 5000/128 or 39 indicates the factor by which the existing illumination of 10 footcandles must be multiplied in order to raise the task to the desired supra-threshold visibility-level. Thus, in order to obtain the desired supra-threshold visibility-level of 9 it is necessary to provide 10 times 39 or 390 footcandles for this specific task. The same result is obtained with the scale of log-units. The difference between 3.7 and 2.11 is 1.59 which is the number of log-units that must be added to the logarithm of the existing footcandle-level. In other words, 1.59 added to 1.00 (the logarithm of 10) equals 2.59, which is the logarithm of 390 and the desired illumination is 390 footcandles.

Either the scale of relative footcandles or the logarithmic scale can be applied to the Luckiesh-Moss Visibility Meter. Both yield identical results, as is illustrated by the preceding example. It is evident that the scale of relative footcandles is con-

TABLE III.—Differences in Log-Units Between Footcandle-Levels Required for Visibility-Levels of 7 and 8 for Test-Objects of Various Sizes and Contrasts

Per Cent Contrast	Size										
	1	1.5	2	2.5	3	4	5	7	10	15	20
95	—	0.10	0.09	0.09	0.07	0.08	0.08	0.09	0.08	0.08	0.08
90	—	0.10	0.09	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.08
80	—	0.10	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.08
70	—	0.09	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08
60	—	—	0.09	0.10	0.09	0.08	0.08	0.08	0.08	0.08	0.08
50	—	—	0.09	0.10	0.10	0.08	0.08	0.08	0.07	0.08	0.08
40	—	—	0.09	0.09	0.10	0.09	0.09	0.08	0.07	0.08	0.07
30	—	—	—	0.09	0.10	0.09	0.08	0.08	0.08	0.08	0.08
20	—	—	—	0.09	0.10	0.10	0.09	0.09	0.07	0.08	0.07
15	—	—	—	—	0.09	0.10	0.09	0.09	0.07	0.08	0.08
10	—	—	—	—	—	0.08	0.09	0.08	0.08	0.08	0.08
5	—	—	—	—	—	—	0.07	0.08	0.07	0.08	0.08

TABLE IV.—Comparison of Log-Units of Illumination Above Threshold Footcandle-Level and the Relative Footcandles for Samples of Printed Matter (Black Print on White Paper) as Obtained by Direct Observation and by the Use of a New Scale for the Luckiesh-Moss Visibility Meter

Task	Visibility-Level	Footcandle-Level	Threshold Footcandle-Level	Log-Units Above Threshold		Relative Footcandles	
				Observed	New Scale	Observed	New Scale
A. Samples from a technical publication							
8-point type	2.80	10	0.022	2.66	2.68	455	480
6-point type	2.30	10	0.042	2.38	2.40	238	250
B. Samples from three dictionaries							
Defined Words							
Sample 1	2.28	10	0.036	2.44	2.40	275	250
Sample 2	2.49	10	0.013	2.89	2.93	770	850
Sample 3	2.83	10	0.024	2.62	2.68	416	480
Definitions							
Sample 1	2.36	10	0.026	2.59	2.43	384	290
Sample 2	2.76	10	0.023	2.60	2.66	400	450
Sample 3	2.45	10	0.026	2.59	2.50	384	360

siderably easier to use, since it involves easily calculated ratios, whereas the log-unit scale involves odd exponentials. Scales for converting the present scale of visibility-levels of this visibility meter to relative footcandles and log-units above the threshold are presented in Fig. 2.

A further check of these new scales is presented in Table IV. These data were obtained by a skilled observer possessing average normal vision. The visibility-levels of several samples of printed matter were determined when the samples were illuminated with 10 footcandles. The threshold footcandle-levels were obtained by reducing the illumination to the point where the observer could just barely read the printed matter. The log-units of illumination above the threshold footcandle-level were obtained (a) by determining the number of log-units that 10 footcandles are above the observed threshold footcandle-level and (b) from the upper conversion scale of Fig. 2. For example, for the sample of 8-point type printed with black ink on white paper the difference between the logarithms of 10 and 0.022 is 2.66. From the upper conversion scale of Fig. 2, the number of log-units above threshold, corresponding to a visibility-level of 2.8, is 2.68. Similarly, the relative footcandles were obtained from the observed footcandle-levels and from the lower conversion scale of Fig. 2. It is seen that the ratio between 10 footcandles and the threshold footcandle-level of 0.022 is 455 which is in satisfactory agreement with the value of 480 obtained from Fig. 2 for a visibility-level of 2.8. The data obtained with other samples of printed matter indicate correspondingly good agreement between observed values and those obtained from the calibration data of the visibility meter.

From the foregoing it appears evident that the new scale of relative footcandles is a convenient and useful addition to the Luckiesh-Moss Visibility Meter for determining footcandle-levels corresponding to desired visibility-levels. Also, when so desired, the visibility-level of a task may be expressed either in terms of relative footcandles above the threshold or as log-units above the threshold footcandle-level. When incorporated in the meter, the new scale will require no charts or tables for its use. However, it still will be necessary to take the necessary precautions when using the meter and to apply the personal correction-factor to compensate for variations from the standard observer. These have been adequately described elsewhere.[3]

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ATTENTION I.E.S. MEMBERS

Don't forget that the National Technical Conference is a month earlier this year. Plan to be in Pasadena, California, Huntington Hotel, August 21-25.

In the Garment Industry

The lighting of Saba of California, one of Los Angeles' largest dress manufacturers, represents the results of a complete study by experts in several fields, of the industrial task involved.

The two cutting tables are illuminated by two-lamp industrial type fixtures mounted approximately four feet above each table in continuous rows. Each cutting table required 21 fixtures. Initial values averaged 100 footcandles, with shadows at a minimum.

In the operating department, machines are placed in lines of nine and eleven, depending on the physical layout of the department, and on American Safety Rules. Illumination is provided by continuous rows of two-lamp industrial type fixtures mounted approximately eight feet from the floor and spaced six feet between rows. Initial illumination value was 100 footcandles on the working surfaces. All supplemental lighting was removed.

The company reports production increases of 37.5 per cent, with greatly improved workmanship.

Industrial Lighting

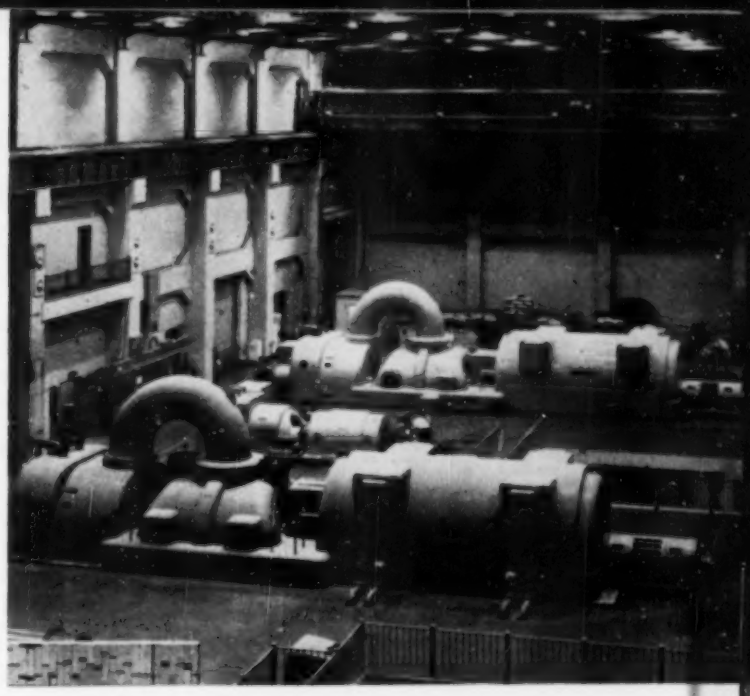
In a Motor Plant

The McCulloch Motor Corporation of Los Angeles originally manufactured revolving blade lawn mowers, but has since expanded into many items utilizing gasoline driven motors. One of the special items of interest is the 4-cylinder, 2-cycle, 65-hp engine of the aviation type used to drive the radio controlled target planes used by the military.

Lighting in the plant consists of continuous rows of four-lamp industrial type fixtures using 120-ma cold cathode lamps. Spacing between rows is 10 feet and the mounting height above the floor is 11 feet. Average illumination level on the machines is 45 footcandles. The factory consists of three units 40 feet wide by 400 feet long, with a total area of 48,000 square feet. Approximately 600 fixtures are used in the plant, with an additional 400 used in the office and engineering units.

In a Generating Station

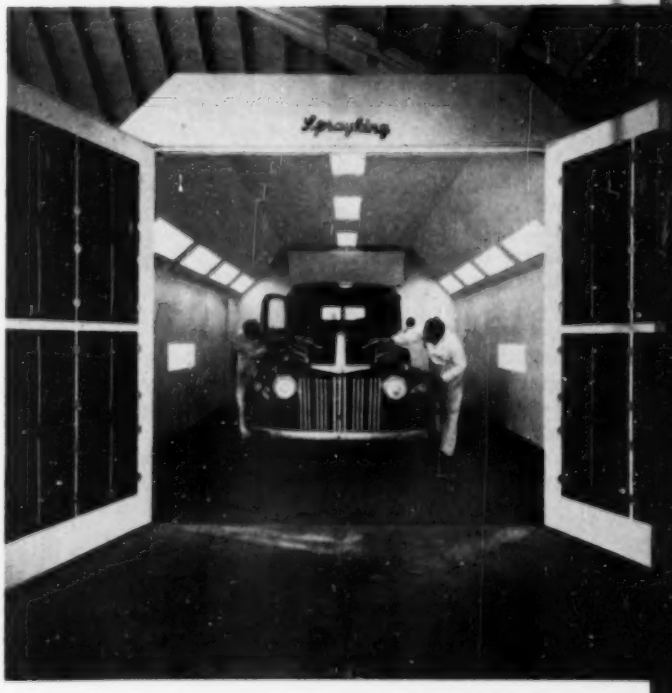
The Harbor Steam Plant at Wilmington, California, was relighted this year using a combination of mercury vapor and incandescent sources. The fixtures were mounted in pairs on the 49-foot ceiling. The generating station is 475 feet long by 100 feet wide, with no natural light available. Reflection factor of the walls is 70 per cent. Illumination values over the area average 35.6 footcandles.



in Southern California

In a Paint Spraying Booth

The "Sprayking" paint spraying booth at the Commercial Air Conditioning Co., Los Angeles, features an interesting lighting solution. Some 15 industrial type fluorescent fixtures have been mounted flush with the interior of the booth, with ¼-inch wireglass lens. Each fixture is equipped with two 4500K white lamps. Initial illumination on the working surface of a car being painted is 78 footcandles, with a maintained value of 62 footcandles. Several later models have been made having viewing windows along the sides, and with air filtering doors to relieve low pressure conditions set up by the exhaust fan, as well as to assure dust-free circulation of air.



Short Arc Mercury Lamps

By GEORGE A. FREEMAN

The development progress of short arc mercury lamps is covered in sizes of 5 to 10 kilowatts power and arc lengths of a half inch or less which have brightness comparable to high intensity carbon arcs. Data are presented on brightness, color, and distribution of light output. A pulse type of starting circuit is described that will automatically start and instantly restart lamps without relays or other moving parts.

QUARTZ mercury lamps were introduced commercially in 1936. Some knowledge had been accumulated at that time about seal design, to utilize the high melting temperature of fused silica (quartz) glass in making more concentrated and more efficient mercury lamps. Even then short arc mercury lamps were being investigated, although limited to the low power of a few hundred watts.[1]

Techniques in making quartz mercury lamps were continually improved during the subsequent decade, as the familiar high intensity mercury lamps in sizes from 100 to 1000 watts were developed and applied to flood, industrial, and street lighting.[2] These lamps were not designed for high brightness and had arc lengths of one to five inches. The desired feature in short arc mercury lamps is high brightness which is achieved by shortening the arc length and increasing wattage per unit of arc length a hundred-fold. Short arc mercury lamps of 1000 watts and higher ratings were made experimentally during the war by a number of lamp companies in England, Germany, and Japan.[3,4] Since the war, the development of short arc mercury lamps was resumed in this country.

The intended purpose of the new lamps is to provide a new light source for such applications as searchlights and motion picture studio lighting.

Quartz Bulb Design

Fused silica is the material used for the envelopes as it is the only transparent material tested so far able to withstand temperatures exceeding 1000°C with the high mechanical strength to contain mercury pressure up to 150 pounds per square inch (10 times atmospheric pressure). The bulb loading is usually 25 to 35 watts per square centimeter of bulb surface. It represents a compromise between deterioration of quartz when the loading is too high, and excessive running up time after lamp starting, if the loading is too low. This loading is two to three times that used for general lighting quartz mercury lamps where several thousand hours' life is required.

Forced air cooling has been tried to permit higher bulb loading but the cooling is often uneven, resulting in bulb strains and failures. Free air cooling is used as it gives more dependable performance.

The bulb for the 10-kilowatt lamp has a spherical shape, four inches in diameter with a heavy $\frac{5}{16}$-inch thick wall. At the present time, the quartz bulbs are hand made requiring considerable skill.

Seal Design

The necessity of providing lead-in conductors capable of carrying currents of 100 amperes or more into the quartz bulb imposed a major problem. The coefficient of thermal expansion of quartz is very low, only a tenth that of tungsten or molybdenum metal used as conductors. A special design is required that will not cause excessive strain when such different materials are hermetically sealed to each other.

The seal design, used until quite recently, consisted of thin molybdenum ribbons sealed into the annular space between two concentric quartz tubes. The ribbons are only a half a thousandth of an inch in thickness in order to set up the least possible strain in the surrounding quartz. Ten ribbons, each $\frac{3}{8}$ inches in width, are spaced in the quartz and connected in parallel so that each may carry its proportionate share of the total current. The lamp of Fig. 1 employs seals of this design.

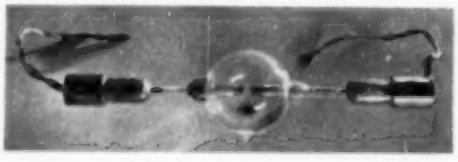


Figure 1. 7.5 kw a-c lamp with molybdenum ribbon seals.

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: Westinghouse Electric Corp., Bloomfield, N. J.

Figure 2. 400-watt type EH1 mercury lamp with molybdenum ribbon seals.

Another example of the use of molybdenum ribbon seals is in the 400-watt type EH1 mercury lamp, as shown in Fig. 2. They are used here to provide the dependability over the long life required for applications such as highway lighting. Although the current is low enough in the 400-watt lamp to require no more than a single ribbon, one of the seals uses a pair of ribbons so that a lead-in is brought to a starting electrode as well as the main electrode.

The dependability of molybdenum ribbon seals is due to the fact that only two refractory materials, quartz and molybdenum, are used which do not deteriorate in time from temperature or electrolysis effects as may happen with softer bead glass. For short arc lamps, however, multiple ribbon seals are more complex and difficult to make as higher current carrying capacity is desired. For this reason it was practical to consider other designs for carrying currents over 100 amperes.

The short arc lamp in Fig. 3 employs molybdenum conductors ¼ inch in diameter which extend the current capacity to 300 or 400 amperes. The new design is much more easily adapted to production line manufacture and can be made larger for still higher current if desired.

Electrode Design

Concentration of high wattage in so small an arc results in a very high temperature at the electrode tips. Tungsten is used because it is the most refractory metal available. However, its melting point of 3370°C is easily exceeded in attempting to obtain maximum arc brightness. This fact puts a ceiling on brightness until a more refractory electrode material is developed.

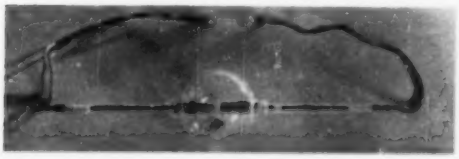


Figure 3. 10 kw a-c lamp with ¼-inch molybdenum rod seals.

The merit of a tungsten electrode is determined by its ability to conduct heat away from the electrode tip. Operation of an electrode at its melting point results in very rapid blackening of the quartz envelope from tungsten evaporated from the electrode tips. A compromise either in lower wattage or longer arc length is made in a practical lamp design.

The electrode design in the 10-kw lamp of Fig. 3 is made quite massive and proportioned to prevent too much shielding of the light output. Swaged tungsten is used to obtain high density for the best heat conductivity.

Short arc mercury lamps can be adapted for a-c or d-c operation. Lamps for both types of power have been made. The 10-kilowatt d-c short arc lamp in Fig. 4 has a relatively small cathode and a large anode. At the cathode, the emission of electrons has a cooling effect making a large mass unnecessary for dissipating heat. The reverse is true at the anode where electron bombardment has a heating effect so that the anode must dissipate about 30 per cent of the power input to the lamp as heat. The electrode heat problem in the d-c lamp is eliminated at one of the two electrodes but it is multiplied by two in the other.

Figure 4. 10 kw d-c lamp with ¼-inch molybdenum rod seals.

Arc Brightness

High brightness is the essential feature for a lamp for optical projection work. The brightness values in Table I are expressed as the maximum brightness of the radiating surface in candles per square millimeter. This table gives representative figures for the short arc mercury lamp compared with other types of available sources.

TABLE I.—Brightness Comparison of Various Types of Light Sources

Tungsten filament	1 to 20 c/sq. mm
Medium pressure mercury	1 to 5
Water cooled high pressure mercury	200-300
Short arc medium pressure mercury	400-1000
High intensity carbon d-c arc	500-1000
Sun	1650

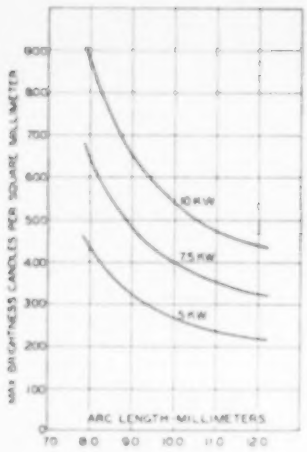


Figure 5. Effect of arc length on brightness.

The relationship between brightness and arc length obtainable from short arc lamps operated between 5 and 10 kilowatts on alternating current, is given in the curves of Fig. 5. The practical brightness limit at the present time, considering the rapid bulb blackening should electrodes become melted, is about 500 c/sq mm. At this level 50 or more hours useful lamp life may be obtained.

Fig. 6 shows a typical arc brightness distribution for a 7.5-kilowatt a-c short arc mercury lamp. Fig. 7 shows the spatial distribution of light output.

Color of Light

The color of the light output is similar to other high pressure mercury lamps with the usual strong mercury line spectrum and a background of continuous spectrum producing a bluish white appearance. It is well known that the continuous spectrum background becomes more pronounced as the pressure is increased.[2] This has been of particular interest in the red region between 6000 and 7000 Angstroms wavelength since no strong mercury lines exist there.

Table II shows that the percentage of luminous radiation in the red region of short arc mercury

TABLE II. Comparison of Red Radiation of Various Light Sources

Lamp Type	Mercury Pressure	Percentage of Luminous Output Above 6000 Angstroms
A10* mercury	4 atmospheres	9
A11	1.2	1.0
A14	8.0	2.0
A16	100	5.5
Short arc mercury	8.0	5.5
Short arc cadmium-mercury	5.0	10
Sun		20
500 watt filament		27

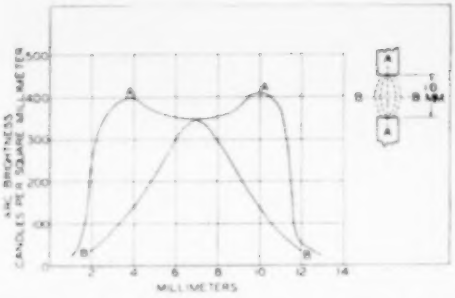


Figure 6. Brightness distribution across the arc of a 7.5 kw short arc lamp.

lamps compares with other mercury arcs of much higher pressure. There is still a shortage of red output, however, as compared to other familiar light sources.

Cadmium and zinc metals have been added to the mercury content to increase the red output since both these metals have spectral lines in the red region. Cadmium-mercury lamps having 10 per cent of the luminous output in the red region have been tested and found suitable for such applications as motion picture studio lighting for color photography. The color may not be quite suitable for some applications, as in color motion picture projection where the light reaches the eye, since it does have a green appearance.

Phosphors have recently been developed for ob-

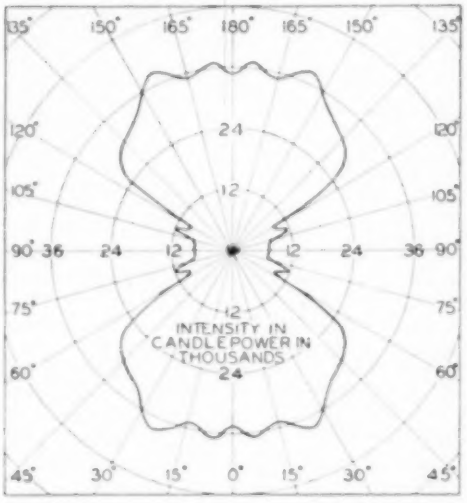


Figure 7. Spatial distribution of light output through a vertical plane from a 7.5 kw short arc mercury lamp.

taining a very pleasing color balance, with 8 to 10 per cent red output, from high pressure mercury lamps. The phosphor converts ultraviolet output from the arc, that otherwise might be wasted, to radiation in the red region above 6000 Angstroms. Phosphors are not suitable for short arc mercury lamps, however, because the high arc brightness necessary for projection would be masked. Color correction with phosphors has the advantage of a slight gain in efficiency while cadmium-mercury lamps have 10 to 20 per cent lower efficiency.

Starting Circuit

During the development of short arc mercury lamps it was necessary to solve circuit difficulties of a special nature. The ability to start quickly and restart a hot lamp was considered necessary wherever short arc mercury lamps might be used. As is well known, a high pressure mercury lamp will not restart on the usual ballast transformer circuit while it is hot from having just been turned off. It is necessary to wait several minutes for a lamp

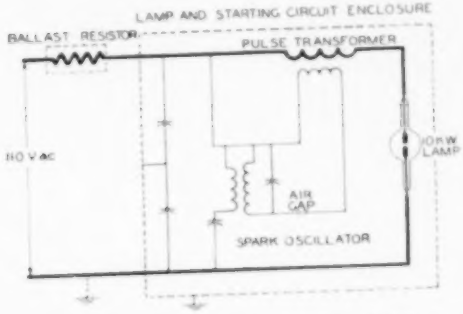


Figure 8. Circuit for starting short arc lamps.

to cool. Various means have been proposed in which high voltage is applied momentarily but in each case required a complicated circuit with several relays or other moving parts that require maintenance.[5]

A new circuit has been developed that will start or restart short arc lamps automatically without relays or other parts that would need frequent attention. The circuit is shown in Fig. 7 and consists of a spark gap oscillator and a pulse transformer to apply a succession of high frequency pulses to the lamp. The pulse voltage is about 50 kilovolts which is sufficient to ionize mercury at high pressure. There is sufficient momentary power to provide the necessary conditions for the arc to start instantly.

The starting circuit components are selected to be voltage sensitive so that when the arc starts, and thereby lowers the voltage across the lamp, the starting circuit automatically deactivates itself. If a power interruption extinguishes the arc it would automatically restart the instant power was restored.

The circuit as shown in Fig. 8 is for an a-c lamp. It can be used on a d-c lamp if alternating current of low power is supplied to the starting circuit input.

Lamp Ballast

The lamp is operated from a 100- to 120-volt a-c source using a series connected resistor or resistor plus reactance ballast. When the lamp is warmed up the arc voltage is between 60 and 75. However, when the mercury arc first starts the arc voltage is low, usually 10 or 15 volts. If the same ballast is used for starting, as is used during full operation, the starting current may be nearly double the operating current. This is desirable as it shortens the running up time to five minutes or less. However, it is necessary for the power source and ballast to be capable of supplying the higher starting current. Otherwise, an adjustable ballast may be used if a longer running up time is not objectionable.

Position of Burning

The most favorable position of burning is with the electrodes one above the other. The upper electrode disperses hot convection currents of mercury vapor preventing a concentration of heat on any spot in the bulb. When the lamp is tilted or operated with the arc horizontal, a luminous flame can be seen indicating the existence of a hot stream of vapor rising from the arc. The bulb may be overheated in a small area above the arc where the hot stream strikes it.

It has been found possible to deflect this stream by means of a magnetic field. The luminous vapor acts in the same way in the presence of a magnetic field as a metal wire carrying current. A weak magnetic field passing horizontally through the arc, at right angles to the plane of the electrodes and the vapor stream, can force the vapor stream downward. The magnetic field is obtained with an electromagnet connected across the lamp terminals.

Fixture Design Requirements

In designing fixtures for short arc lamps, there are several special factors to consider. The starting circuit components must be located within a few feet of the lamp to function properly. The high voltage pulse must be conveyed to the lamp re-

TABLE III.—Tentative Characteristics of 10 Kilowatt Short Arc Mercury Lamps

Wattage	10 kilowatts
Supply	100-120 VAC
Rated average life (hours)	50
Maximum arc brightness (initial)	500 c/sq mm
Lumens (initial)	550,000
Arc length (millimeters)	10
Arc width to half brightness (millimeters)	5
Bulb diameter (inches)	4
Maximum overall length (inches)	30
Arc voltage	60-75
Arc current (amperes)	175
Maximum starting current (amperes)	300
Operating position	Vertical *

*Other positions with magnetic field or other means to prevent overheating quartz bulb.

quiring insulation for 50 kilovolts that will withstand temperatures up to 200°C.

The lamp emits a large amount of ultraviolet radiation and produces ozone from the oxygen in the surrounding air. The materials used in the fixture must be ozone resistant. The light must not escape without first passing through glass to absorb radiations dangerous to the human body.

Since the internal mercury vapor pressure of the lamp is above atmospheric, the possibility of violent failure must be considered. Even though the likelihood of a burst is small, the fixture must be able to withstand it and retain the broken quartz.

The existence of starting pulses of high voltage requires that the fixture be grounded or connected by means of condensers to one or both sides of the power line circuit, as shown in Fig. 8.

The new high current seals permitting high starting current and the use of the new starting circuit, have made it possible to reach full brightness fairly quickly. These improvements may make special arrangements for stand by, such as simmering enclosure, unnecessary.

Table III is presented as a summary of the important characteristics of 10-kilowatt short arc mercury lamps as they stand today. The development is progressing favorably toward commercial availability in the near future.

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DISCUSSION

F. D. WYATT*: This paper records another milestone in the development of artificial lighting sources. Mr. Freeman is to be highly commended for the research and development program which has produced a larger capacity mercury lamp with better color distribution and with instant start and restart.

In the paper presented by Edward B. Noel at the Boston meeting September 21, 1948, a request was made on the improved lumen output and performance of mercury lamps, which had been made during the preceding year. In discussing that paper, I stated that the lamp users desired an improvement in color distribution and a reduction of starting and restarting time.

It is very gratifying to see the large amount of work which has been done in the past year in improving these two characteristics of mercury lamps. This paper indicates that progress is continuing to be made in mercury light sources. Mr. Freeman and his company are to be commended for this progress.

C. R. DAILY**: The short arc mercury lamp may find wide use for motion picture stage lighting as a supplement, and as a replacement for the carbon arcs which are now widely used for color, and in some cases, for black and white photography.

The present carbon arc lamp is bulky, sometimes temperamental in its burning, a possible source of noise and smoke, and requires close supervision while in use. A short-arc mercury lamp ought to provide the desired basic simplicity of tungsten lamp operation which includes remote starting facilities, reduced attendance by stage personnel during operation, essentially instantaneous re-start, no smoke and no noise. The new lamp should considerably reduce the stage and shop maintenance now required with carbon arcs, and their associated carbon feeds, motors, etc.

As a light source the new mercury arc must have a color which is satisfactory for standard color photographic processes, which will require more green and red than has been available in the earlier types of mercury arcs. The useful light output of the lamp in its fixture must also exceed that of a standard type 150-amp high intensity d-c carbon arc, and must also provide an even light distribution with simple spot-to-flood control.

The mercury arc also must be capable of burning with the light shining from almost straight down to nearly straight up. The physical strength of the lamp and its associated equipment must be capable of taking the normal handling abuse required during moves from stage-to-stage and subsequent rapid installation and removal.

G. A. FREEMAN***: High wattage short arc mercury lamps with cadmium added to the mercury content appear capable of meeting the requirements outlined by Mr. Daily for motion picture studio lighting.

*Chicago Park District, Chicago, Ill.
**Engineering Dept., Paramount Pictures, Inc.
***Author.

Lighting an Eight-Lane Highway

LIGHTING OBJECTIVE: To provide the proper quantity and distribution of illumination for safe visibility on the "world's busiest highway."

Installation on New Jersey Route 25 near Newark Airport

General Information: Referred to by the U. S. Bureau of Roads as "the world's most heavily-traveled artery," New Jersey's Route 25 through the Jersey City-Newark-Elizabeth sector carries daily averages of 60,000 vehicles with occasional peaks greater than 102,000. The highway is composed of twin two-lane express roadways with flanking double-lane roadways for local traffic. North and southbound express roadways are separated by a continuous, raised, 16-foot-wide central island, while express and local unidirectional traffic are separated by two-foot reflecting curbs. Each two-lane paved roadway is approximately 34 feet wide.

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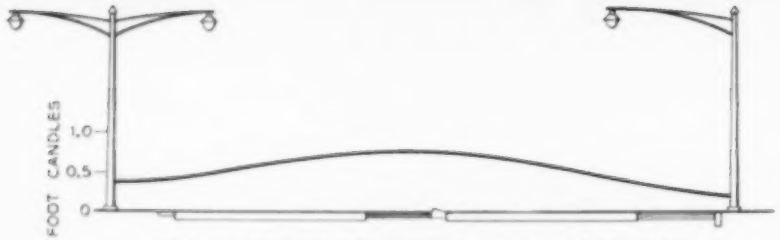
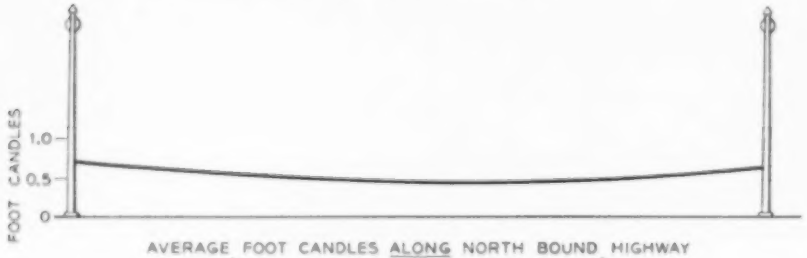


AVERAGE FOOT CANDLES ACROSS NORTH BOUND HIGHWAY
(SOUTH BOUND SAME AS NORTH BOUND)
OVERALL AVERAGE F.C. INTENSITY = 0.526



AVERAGE FOOT CANDLES ALONG NORTH BOUND HIGHWAY
(SOUTH BOUND SAME AS NORTH BOUND)
OVERALL AVERAGE F.C. INTENSITY = 0.526

Installation: Westinghouse AK10 luminaires with Holophane #4117 refractors are mounted 25 feet above the pavement on Union Metal Design Series #6400 standards stagger-spaced every 87.5 feet along the highway for 3.2 miles (a total of 477 lamps). Double unit standards with 12-foot arms are employed in the center parkway, with 15-foot arm, single-lamp units located 2 feet, 8 inches behind the faces of the outer curb lines. The resultant transverse distance between lamps is 52.7 feet. All luminaires contain 6000 lumen PS40, 20-ampere, series incandescent lamps. Light is asymmetrically directed in accordance with standard Type III distribution. Coefficients of utilization are 0.51 on the street side and 0.06 over the shoulders on the rear areas.

The average calculated illumination is 0.526 footcandles with peaks of 1.15 directly opposite each twin-light center-island standard.

Lighting data submitted by Bruce J. Jensen, Public Service Electric and Gas Company, Newark, New Jersey as an illustration of good lighting practice and to aid in the design of similar installations.

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The Determination of Color Parameters of Fluorescent Lamps

By CHARLES W. JEROME

It is frequently desirable to be able to compute parameters of fluorescent lamps for the I.C.I. color mixture diagram from their spectral energy distributions. A search of the literature for such a method has proven fruitless. Consequently, a method has been evolved and is described herein. A comparison is made between the values of several lamps so measured with their values measured on a four filter colorimeter[1] and with values determined by the National Bureau of Standards, and Electrical Testing Laboratories.

WE HAVE available in our laboratory a spectroradiometer designed by Mr. S. L. Parsons and constructed at the Sylvania Research Laboratories at Flushing, N. Y.[2] This radiometer employs a Beckman spectrograph[3] with an automatic slit width adjustment such that the exit slit has an effective width of 5 mu at all times. A suitable measuring and recording instrument records the relative energy as a function of wavelength of any luminous source irradiating the entrance slit of the spectrograph. A reproduction of a typical fluorescent lamp curve drawn by this instrument is shown in Fig. 1.

As indicated in Fig. 1 the spectral energy distribution of a fluorescent lamp consists of two distinct parts: (I) a continuous spectrum which is due to the phosphor coating of the lamp, and (II) the mercury line spectrum which is superimposed on the continuous spectrum. The x and y values for a continuous spectral distribution such as that due to (I) above can be easily computed by the Selected Ordinate method.[4] However, the mercury lines, (II) above, contribute appreciably to the color of the lamp and must be taken into account in determining the color parameters. Therefore, in order for the selected ordinate method to be used in this case, the relative energy of the mercury lines as recorded by the spectroradiometer as compared to the recorded energy of the continuous spectrum of the phosphor must be properly evaluated and integrated into the summations made in the x and y computation.

Mary P. Lord[5] treated the comparative evaluation of the energy of mercury lines when they are present with a continuous spectrum. She used a double monochromator with fixed slit widths and arrived at the solution that the energy of the line equals the difference between the total energy and that of the continuum, multiplied by a function of the slit widths and linear dispersion of the monochromator. She evaluates the above function for the three major cases of relationships between the various slit widths. No attempt has been made in the following discussion to evaluate the corresponding function for our instrument but it has been combined into one "instrumental constant," K. In determining x and y values this constant cancels out and hence its evaluation is not necessary.

In order to evaluate the relative recording of the mercury lines and the continuous spectrum, it is necessary to consider the passage of light through the spectrograph in the two cases. In either case, the optical system of the spectrograph forms an image of the entrance slit in the plane of the exit slit. Consider first the case of monochromatic radiation and the prism so oriented that the image of the entrance slit is immediately adjacent to, but wholly outside of the exit slit, *i.e.*, no radiation is passed by the latter. If both entrance and exit slits are the same width, as for the Beckman, the center of the image will be at a distance, d, from the center of the exit slit, where d is the width of the slits expressed in effective wavelength units. As the orientation of the prism is now changed, a small portion of the entrance slit's image will be passed by the exit slit and will be picked up and measured by the phototube. This will increase linearly until the center of the image corresponds to the center of the exit slit at which setting all the energy of the image is passed by the exit slit and measured by the phototube. Thereafter, as the image passes on out of the field of view of the exit slit less and less of the image will be passed and the recording will decrease to zero again when the center of the image is at a distance, d, from the center

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: Sylvania Electric Products Inc., Salem, Mass.

of the exit slit. Therefore, for monochromatic radiation, the peak recording is a true measure of the relative energy contained therein.

When a continuous spectral radiation illuminates the entrance slit, for one wavelength all the energy will be passed by the exit slit. However, there will also be adjacent wavelengths a portion of which will be passed by the exit slit and contribute to the response of the phototube. The amount of these adjacent wavelengths passed will be directly proportional to the difference between their wavelengths and that for which the spectrograph is set, becoming zero at wavelengths, $\lambda = d$. Therefore, if the amount of radiation passed by the exit slit is plotted as a function of the wavelength, an isosceles triangle results with the apex at the wavelength, λ, for which the spectrograph is set and being $2d$ wide at the base, where d is the effective slit width. The phototube integrates all this radiation. That is, its response is proportional to the area under this curve which is $\frac{1}{2} \times 2d \times a = ad$, where a is the altitude of the triangle, or the energy per unit wavelength.

Therefore, a continuous spectral distribution of radiation which has an energy per millimicron equal to that of a monochromatic source, *e.g.*, mercury lines, will give a recording 5 times as great as the monochromatic source when the slits used are 5 millimicrons wide. Therefore, in the case of the curves drawn by our radiometer for the mercury lines to be placed on an equal footing with the continuous spectrum their recorded heights over that of the continuum must be multiplied by 5.

In the selected Ordinate method of x and y computation successive intervals, $\Delta\lambda$, are chosen such that $\bar{x}_\lambda \Delta\lambda$ etc. is a constant. In the case where 30 ordinates are used each of these products is equal to 3.560 when λ is in millimicrons. Expressed in equation form:

$$\bar{x}_\lambda \Delta\lambda = 3.560 \quad \text{or} \quad \Delta\lambda = \frac{3.560}{\bar{x}_\lambda}$$

$$\bar{y}_\lambda \Delta\lambda = 3.560 \quad \text{or} \quad \Delta\lambda = \frac{3.560}{\bar{y}_\lambda} \qquad (1)$$

$$\bar{z}_\lambda \Delta\lambda = 3.560 \quad \text{or} \quad \Delta\lambda = \frac{3.560}{\bar{z}_\lambda}$$

For a mercury line to be integrated into the summations used in the computation of x and y, its recorded energy not only must be multiplied by 5 but also it must be considered as spread evenly over the interval of $\Delta\lambda$ in which it occurs. That is, its energy must be divided by the appropriate $\Delta\lambda$. The resulting value can then be added directly to the summations of the selected ordinates for the continuous spectrum. Therefore, the quantity to be added is:

$$\frac{5R_{Hg\lambda}}{\Delta\lambda} = \frac{5R_{Hg\lambda}\,\bar{x}_\lambda}{3.560} \qquad (2)$$

with similar expressions involving $\bar{y}_\lambda$ and $\bar{z}_\lambda$.

Since the expressions $\frac{5\bar{x}}{3.560}$, $\frac{5\bar{y}}{3.560}$, and $\frac{5\bar{z}}{3.560}$ occur continually in computing the mercury line color contribution, they have been evaluated for each of the four wavelengths of the mercury lines involved and are given in Table I. For convenience the notation $\bar{x}$, $\bar{y}$, and $\bar{z}$ respectively have been adopted for these quantities.

TABLE I.—I.C.I. Tristimulus Values, and Modifications at Wavelengths of Mercury Spectrum

(m_μ)	$\bar{x}$	$\bar{y}$	$\bar{z}$	$\bar{x}$ $\left(\frac{5\bar{x}_\lambda}{3.56}\right)$	$\bar{y}$ $\left(\frac{5\bar{y}_\lambda}{3.56}\right)$	$\bar{z}$ $\left(\frac{5\bar{z}_\lambda}{3.56}\right)$
405	.0232	.0006	.1105	.0325	.0008	.1553
435	.3268	.0168	1.5142	.4590	.0235	2.2673
546	.3741	.9840	.0123	.5255	1.3820	.0173
578	.8877	.8890	.0016	1.2468	1.2485	.0023

The mercury lines' intensities for normal fluorescent lamps vary over a rather narrow range. Therefore, when a large number of curves are to be measured it would be convenient to prepare a table of $R_{Hg}\bar{x}$, $R_{Hg}\bar{y}$, and $R_{Hg}\bar{z}$ covering the range of intensities normally encountered.

Using the method outlined above, the x and y values of the lamp whose spectral energy distribution is shown in Fig. 1 may be computed.

Using the appropriate 30 selected ordinates, the

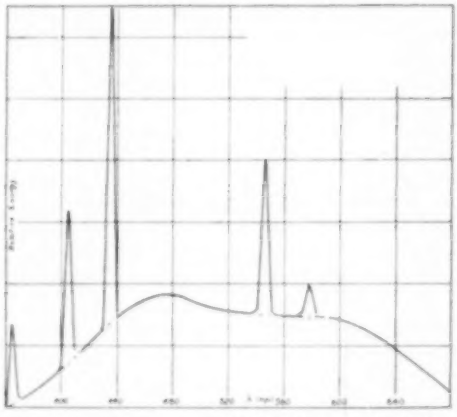

Figure 1. Spectral energy distribution. 40-watt T-12 fluorescent lamps, 6500° daylight.

following summations for the continuous spectrum due to the phosphor are found:

$$X_p = 808.0$$
$$Y_p = 875.2$$
$$Z_p = 923.4$$

The mercury line intensities recorded above that of the continuum are:

$$R_{405} = 48.6$$
$$R_{435} = 102.2$$
$$R_{546} = 49.9$$
$$R_{578} = 10.5$$

Using these values, the products $R_{Hg}\bar{x}$, etc. are:

mμ	$R_{Hg}\bar{x}$	$R_{Hg}\bar{y}$	$R_{Hg}\bar{z}$
405	1.6		7.5
435	46.9	2.4	231.7
546	27.6	69.0	.9
578	13.1	13.1	
Totals:	89.2	84.5	240.1

Therefore, for the lamp:

$$X_L = X_p + X_{Hg} = 808.0 + 89.2 = 897.2$$
$$Y_L = Y_p + Y_{Hg} = 875.2 + 84.5 = 959.7$$
$$Z_L = Z_p + Z_{Hg} = 923.4 + 240.1 = 1163.5$$
$$\text{Totals} = 2606.6 + 413.8 = 3020.4$$

$$x_L = \frac{897.2}{3020.4} = .297$$

$$y_L = \frac{959.7}{3020.4} = .317$$

If so desired, the color parameters of the phosphor or those of the mercury lines alone can be determined from the data above.

For the phosphor alone:

$$x_p = .310$$
$$y_p = .336$$

For the mercury lines alone:

$$x_{Hg} = .215$$
$$y_{Hg} = .204$$

The color parameters of this lamp as determined on a four-filter colorimeter are:

$$x_L = .315$$
$$y_L = .338$$

The difference between the computed point (.297, .317) and that determined by the colorimeter (.315, .338) is much greater than can be explained on the basis of any normally expected errors involved in either the measurements by the colorimeter or in the method used in the computation. It is further observed that in measurements on a large number of lamps the deviation is quite constant. (See Tables II, III, and IV). This led to an investigation of possible variations in the method of compu-

TABLE II.—Deviations from Measured Values of Computed Color Parameters of Fluorescent Lamps

	Measured		Computed—Deviations from Measured Values with x Decreased 15%			
40 Watt*	x	y	Δx	Δy	Δx	Δy
	.218	.286	—.003	—.015	+.015	+.008
	.311	.332	—.013	—.016	+.005	+.004
	.365	.366	—.019	—.011	—.003	+.006
	.404	.387	—.014	—.008	.....	+.006
	.473	.418	—.006	+.011	+.002	+.018
	.495	.396	—.022	—.005	—.012	+.004
Average Deviation			—.013	—.011	+.001	+.008
30 Watt+						
	.170	.239	—.004	—.020	+.008	+.002
	.184	.187	.....	—.017	+.020	+.001
	.230	.280	—.016	—.008	+.002	+.015
Average Deviation			—.007	—.015	+.010	+.006

*Values Measured by National Bureau of Standards.
+Values Measured by Electrical Testing Laboratories.

TABLE III.—Deviation from Measured Values of Computed Color Parameters of 40T12 Fluorescent Lamps

Measured*		Computed - Deviations from Measured Values with x Decreased 15%			
x	y	Δx	Δy	Δx	Δy
.304	.341	—.018	—.020		—.003
.311	.345	—.015	—.019	+.002	+.001
.315	.338	—.018	—.021	.....	—.001
.315	.343	—.015	—.014	+.002	+.005
.317	.350	—.019	—.020	—.001	.....
.365	.411	—.013	—.019	.....	—.004
.378	.414	—.022	—.035	—.007	—.019
.400	.406	—.013	—.017	.....	—.003
.408	.406	—.016	—.013	—.002	+.001
.411	.402	—.015	—.022	—.004	—.005
.413	.402	—.017	—.020	—.004	—.007
Average Deviation		—.016	—.020	—.001	—.003

*Values measured on Four-Filter Colorimeter after adjustment.

TABLE IV.—Deviations from Measured Values of Computed Color Parameters of 40T12 Fluorescent Lamps

Measured*		Computed - Deviations from Measured Values with x Decreased 15%			
x	y	Δx	Δy	Δx	Δy
.241	.291	—.013	—.011	+.005	+.011
.280	.313	—.005	—.010	+.013	+.012
.308	.326	—.015	—.012	+.003	+.008
.317	.326	—.027	—.030	—.007	—.010
.317	.338	—.014	—.001	+.003	—.014
.366	.362	—.016	—.007	.....	+.009
.368	.362	—.017	+.002	—.002	+.018
.371	.375	—.012	—.003	+.006	+.016
.393	.391	—.015	—.008	—.002	+.007
.393	.396	—.014	+.002	—.001	+.015
.397	.386	—.016	—.011	—.002	+.003
.403	.395	—.016	—.008	—.003	+.005
.405	.386	—.012	.....	+.001	+.013
.413	.384	—.015	+.001	—.002	+.014
.414	.404	—.013	—.010	—.001	+.002
.416	.375	—.013	+.004	.....	+.017
.429	.409	—.015	—.006	—.003	+.006
.440	.415	—.003	—.005	+.007	+.004
Average Deviation		—.014	—.006	+.001	+.008

*Values measured on Four-Filter Colorimeter prior to adjustment.

tation to see whether this difference could be decreased. Other multiplying factors for the mercury lines were tried without any success.

Since the calculations on a majority of the lamps gave x and y values too low, and low by approximately the same amount, this suggested the possibility that the value for Z obtained was too high. A little experimentation showed that if Z were decreased by 15 per cent, values of x and y were obtained which were in much closer agreement with the measured values. Assuming that this is the proper correcting factor, it indicates that the spectroradiometer is recording 15 per cent high in the blue end of the spectrum. In view of the manner in which the radiometer is calibrated, it is quite possible that this error exists. The method of this calibration is to place a standard tungsten filament lamp whose spectral energy distribution is known in front of the entrance slit of the radiometer and then cut a cam to rotate between the exit slit and the phototube and varying in such a manner that the recording apparatus will give a faithful rendition of the known energy distribution of the lamp. The cutting of this cam is an extremely delicate operation and readings within ± 1 scale division (full scale = 100 divisions) are usually considered satisfactory. With the recorder operating near its maximum deflection this variation does not introduce an appreciable percentage error. However, the emission of the tungsten filament decreases rapidly t. .ards the blue end of the spectrum and starting a 100 units at 680 millimicrons it decreases to 16 u its at 445 millimicrons, the point at which $\bar{z}$ is at a maximum. At this point a variation of 1 scale division introduces an appreciable percentage error. The color parameters of the lamps listed in Tables II, III, and IV were also computed with the Z summation decreased by 15 per cent and the results are listed therein. The calculated points for the lamp of Fig. 1 by this procedure are shown plotted in Fig. 2. As would be expected, the computed points for the phosphor, mercury lines, and lamp fall along a straight line with the lamp between the other two points. An error in the calibration of the radiometer, then, can explain the greater part of the differences observed between the measured and calculated values.

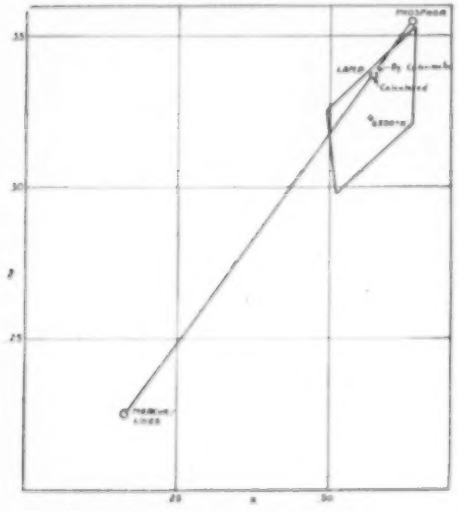

Figure 2. I.C.I. color mixture diagram.

However, there are other factors contributing to deviations between measured and calculated values as evidenced by the variation from lamp to lamp in the deviations given in the Tables. The four main factors which may contribute to this discrepancy are:

1. Operation of the lamp on different ballasts.
2. Errors inherent in the Selected Ordinate Method.
3. Errors inherent in the four filter colorimeter.
4. Other errors inherent in the spectroradiometer.

Concerning (1) above, it has been found that varying the current through a fluorescent lamp will shift its color parameters through a small gamut. By such a procedure, the color of the lamp of Fig. 1 was shifted from its point for normal operation (410 ma) of .315; 337 to .324; 336 for 150 ma and .323; .341 for 750 ma. Since currents from different ballasts will not vary as much as the extreme range chosen here, the color shift due to this cause will be proportionately smaller. However, a small part of any discrepancy between the calculated and observed points can be accounted for by a possible difference in current drawn by the lamp during the measurements. During measurements with the spectroradiometer, provision is made for feeding a constant voltage into the lamp and for maintaining the current constant. The current for every lamp of the same size measured is maintained at the specified amount. Therefore, color measurements by the method described herein are free from this source of variation and lead to more reproducible results than has proved to be the case with the colorimeter.

Errors inherent in the Selected Ordinate method of integration become important only when there is an extreme and rapid fluctuation in energy throughout the spectrum. This does not occur with the phosphors normally used in present day fluorescent lamps. The method described herein for integrating the mercury lines into the selected ordinate

summations of the phosphor is not part of the Selected Ordinate Method but merely a conversion of data to allow its inclusion in that method. Consequently, it is believed that errors due to the Selected Ordinate Method do not contribute in any appreciable degree to the observed discrepancy.

The errors in color coordinates determined by the colorimeter as stated by Dr. Barnes in his paper[1] were $-.001$ in x and $-.002$ in y for daylight lamps. Also, the expected errors vary considerably for other colors. However, when the colorimeter is used over long periods, the transmission characteristics of the filters may change and the shutters shielding the photocells may be jarred out of position and the resultant errors may be considerable. Also, the sensitivity of the photocells is subject to change with time and may contribute to the error. For example, the colorimeter used in our plant was recently readjusted. A comparison of calculated and observed values showed wider variation and less consistency before the adjustment than has been the case since. (See Tables III and IV.)

A further discrepancy introduced in measurements by the colorimeter is due to the photocell + filter combinations used not giving true replicas of the $\bar{x}$, $\bar{y}$, and $\bar{z}$ functions which they approximate. This is overcome in part by calibration of the instrument with standard lamps whose color parameters have been determined by another means. These lamps are then measured on the colorimeter and correction factors applied to the readings to make the latter agree with those determined as true. These correction factors are appreciable and vary widely for different regions of the I.C.I. color mixture diagram. For example, the following are typical correction factors for white and daylight lamps:

	x	y
White	$-.008$	$-.004$
Daylight	$+.001$	$+.006$

Therefore, when measuring lamps whose colors differ somewhat from those of the standard lamps, an unknown variable is introduced since the true correction factors are not known. Also, in some of our experiments, it has been found that lamps with different spectral energy distributions arising from different ingredients being used require different correction factors, whereas the method described in this paper gave results which placed the various lamps tested in their proper relative position as determined by visual comparison regardless of the relative shape of the spectral energy distributions. Therefore, for the ultimate accuracy to be obtained with the colorimeter, it must be calibrated with lamps whose color parameters are known, whose color closely approximates that of the lamp to be measured, and whose spectral energy distribution has the same relative shape.

The discrepancy caused by the lack of correspondence between the photocell and filter combinations and the true $\bar{x}$, $\bar{y}$, and $\bar{z}$ can be shown by a comparison of measurements of the contribution of a typical mercury line spectrum found in a fluorescent lamp by the two methods. In these measurements the recorded heights of the mercury line (a true measure of their relative intensities) are multiplied by the values of $\bar{x}$, $\bar{y}$, and $\bar{z}$ at the corresponding wavelengths for one measurement, and by the corresponding sensitivity of the photocell and filter combinations for the other. The complete calculation is shown below. (Note: The values for the photocell and filter combinations have been adjusted so that $\Sigma E_{H\theta}\bar{z}$ are equal in both cases.)

		$E_{H\theta}\bar{x}$ Photocell + Filter			$E_{H\theta}\bar{x}$ True Values of		
λ	$E_{H\theta}$	$\bar{x}$	$\bar{y}$	$\bar{z}$	$\bar{x}$	$\bar{y}$	$\bar{z}$
405 mμ	45.0				1.0		4.5
435	97.7	39.1	3.8	166.0	32.5	1.8	160.9
546	41.5	11.3	47.7		14.3	40.5	.6
578	9.0	8.9	10.0		7.7	8.2	
		59.3	61.5	166.0	55.5	50.5	166.0

$\Sigma = 286.8$ $\quad x = .207$ $\quad y = .214$

$\Sigma = 272.0$ $\quad x = .204$ $\quad y = .185$

This choice of a line spectrum for this example exaggerates the discrepancy. In the colorimeter an effort has been made to balance discrepancies in one spectral range with discrepancies of the opposite sign in other regions. However, this discrepancy between the true $\bar{x}$, $\bar{y}$, and $\bar{z}$ and their filter + photocell counterparts can be important even with a continuous spectral distribution, since a balance can be thus made for only one spectral distribution and will be thrown off for distributions which vary from the balanced one. Present day fluorescent lamps do vary considerably in spectral distributions from one whose major energy is in the blue, *e.g.*, daylight, to one the majority of whose energy is in the red, *e.g.*, warmtone. Consequently, the above calculation is given as an indication that this discrepancy may contribute to the difference between calculated and measured values, and is particularly important when measuring lamps whose spectral energy distribution has a different shape than that with which the instrument is calibrated.

A possible error contributed by the radiometer, other than that of calibration discussed above, results from a variation in the zero reading, *i.e.*, the height of the recorded curve may be one or two units high or low. This variation is normally in the

form of a drift which is slow enough so that the error involved remains reasonably constant during the time required to make a curve. This error is minimized by adjusting the zero reading prior to running each curve. Assuming such an error it is possible to compute the variation on the color parameters caused thereby. For example, for the first lamp listed in Table II, it was found that a variation of ± 1 unit in the height of the curve throughout the recorded spectrum caused a variation of $\pm .0007$ in both color parameters. This variation in zero setting is typical of the amount of adjustment which has been found necessary in the operation of the spectroradiometer and the resulting errors in x and y are, therefore, also considered to be typical of those resulting from this cause. The magnitude of these errors is seen to be negligible when compared to the usual discrepancy between calculated and measured values.

In conclusion, then, there has been described herein a method of computing the color parameters of fluorescent lamps from their spectral energy distributions. It is believed that this method is freer from day to day variables than beset the use of the four-filter colorimeter and with a more careful grinding of the calibration cam of the radiometer will yield a more rigorous method with which more consistent results can be obtained than is possible with the colorimeter. The latter instrument will undoubtedly continue to be the one used for production control whereas, the method described herein will find its principal use as a check on the colorimeter when errors in its adjustment are suspected, and for the measurement of the color of light sources not readily measured on the colorimeter.

I would like to express my appreciation for the many helpful suggestions and discussions of Dr. E. F. Lowry and Dr. K. H. Butler which contributed materially to the writing of this paper. I am also indebted to Dr. E. T. Barnes of the General Electric Co., and to Dr. L. E. Barbrow of the National Bureau of Standards who very kindly reviewed the original manuscript and pointed out certain discrepancies therein.

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Addendum

Since preparing the foregoing article, considerable work has been done on the preparation of a new calibration cam for the radiometer with a higher accuracy than the old one. The spectral energy distribution curve of the standard lamp drawn by the radiometer with the new cam shows a close agreement with the spectral energy distribution of *Illuminant* A, which has the same color temperature as the standard lamp. (See Figure A1) The color coordinates of the lamp as computed from this curve are: $x = .447$, $y = .409$; those of Illuminant A as set by the International Committee on Illumination are: $x = .448$, $y = .408$. These data indicate that with the new cam, the calibration of the radiometer is sufficiently accurate for the present use.

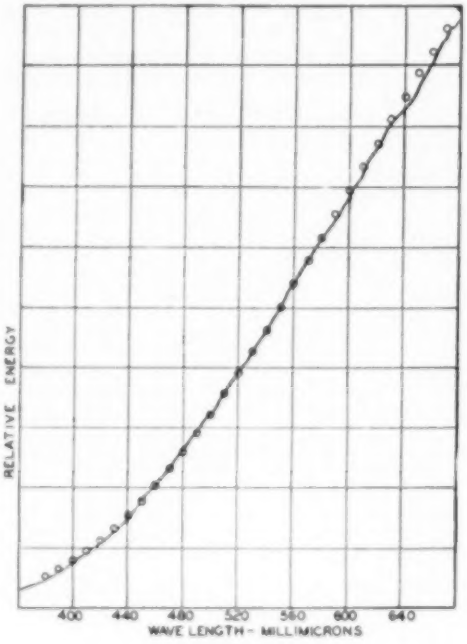


Figure A1

As a further check on this assumption, the curve of a typical fluorescent lamp was modified point by point including the mercury lines for the difference between the radiometer's curve for the standard lamp and that of Illuminant *A*. That is, the fluorescent lamp curve was corrected to what it would be if a perfectly cut calibration cam could be obtained and used. The computed color parameters of the modified curve differed from those of the original body by only $+.001$ in both x and y.

A further change in the calibration of the radiometer is necessitated by the new absolute temperature scale

TABLE AI.—Comparison of Computed and Measured Color Parameters of Fluorescent Lamps

Lamp No.	Bu. Stds.		Computed							
			Old Calibration				New Calibration			
	x	y	x	y	x	y	x	y	x	y
1	.311	.332	.299	.316	−.013	−.016	.305	.328	−.006	−.004
2	.365	.366	.346	.355	−.019	−.011	.350	.360	−.015	−.006
3	.400	.396	.386	.378	−.014	−.008	.391	.387	−.009	+.001
	Barnes									
4	.309	.337	.291	.317	−.018	−.020	.304	.330	−.005	−.007
5	.351	.365	.343	.358	−.008	−.007	.353	.367	+.001	+.002
6	.400	.398	.382	.379	−.018	−.019	.394	.397	−.006	−.001
7	.436	.403	.426	.403	−.010	.....	.427	.408	−.009	+.005
			Average Deviations		−.014	−.013			−.007	−.001

which has been adopted. The magnitude of the resulting change in color parameters is approximately +.002 in x and +.001 in y. Therefore, the present calibration of the radiometer gives an error of approximately −.003 in x and −.002 in y. However, the change in temperature scale does not enter into consideration in the present case, since the measured values are on the basis of the old temperature scale.

Using the new calibration cam spectral energy curves were determined for three lamps whose color coordinates had been determined by the National Bureau of Standards by visual comparisons, and for four production lamps whose color parameters had been measured on the Barnes Colorimeter using the Bureau of Standards lamps as calibration standards. The color parameters of these lamps were computed from the curves and the comparison of results with the old and new cams is shown in Table AI. The relationship on the ICI color mixture diagram between the new computed values for the mercury lines, phosphor and lamp and the measured values are shown graphically in Figs. A2 and A3.

There has been some evidence gathered in recent years that the color sensitvity curve for the "Standard Observer" fails to represent normal observers satisfactorily in the blue end of the spectrum, the normal eye being more sensitive in this region than given by the accepted curve. Consequently, color comparisons made by visual methods will tend to suppress the amount of blue component needed for a match thereby giving color parameters which are too high in x. The final deviations of computed values from those measured as given in the table above show this type of deviation, *i.e.*, the computed x's are in general slightly lower than the measured values.

Dr. D. B. Judd has indicated in a private conversation that visual measurements of several observers at the Bureau of Standards on a single lamp may vary by as much as .005 in both x and y due to slight differences in the color sensitivity of the various observers. The deviations of the majority of the computed points of the lamps in the above table from their measured values approximate this deviation which is taken to be the best agreement that can be expected.

These data are offered as evidence that reasonably close agreement can be obtained between color parameters computed by the method described in this paper and those measured by the Barnes Colorimeter using standards whose x and y values are set by visual measurements.

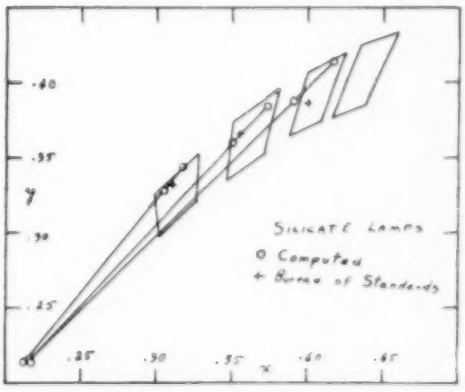


Figure A2

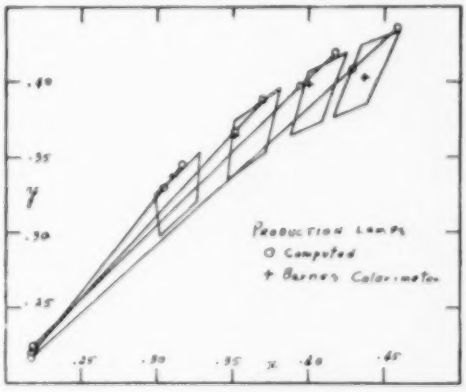


Figure A3

DISCUSSION

L. E. Barrow*: Mr. Jerome has described in this paper an objective method for determining the chromaticity coordinates of fluorescent lamps. The correlation between the results which he obtains objectively and those obtained visually on the same lamps is not too good, but yet it is close enough to make it difficult to assign the existing difference to either of the two methods.

It should be pointed out that a change which has been made in the color temperature scale will make it necessary for Mr. Jerome to recalibrate his spectroradiometer. In a paper which will soon be published in the NBS Journal of Research, Dr. Judd will point out that an incandescent color temperature lamp which previously represented Illuminant *A* (2842°K with C_2 equal to 14320 micron degrees) is now, at the same operating voltage, assigned a color temperature of 2829°K with C_2 equal to 14380 micron degrees. This results in an appreciable change in the computed spectral energy curve of the color temperature standard, but it is doubtful that it will result in great changes in the chromaticity coordinates computed by Mr. Jerome. Recomputation of the results will settle this point.

The only other factor, not mentioned by Mr. Jerome, which comes to mind, which may account for some or all of the outstanding differences in results, is stray radiation. In a single prism radiometer, this is a possible source of error which bears investigation.

C. W. Jerome*: In the paper referred to by Mr. Barlow ("Differences Between the International Temperature Scales of 1948 and 1927" by Robert J. Corruccini, Research Paper RP2014, Vol. 42, August 1949, NBS Journal of Research) the temperature corresponding to 2848°K in the 1927 scale, the color temperature taken as Illuminant *A* in my past computations, was found to equal 2835°K in the 1948 scale. Using this temperature, and $C_2 = 14380$ micron degrees, the emissivity of J_λ was computed and the color parameters computed therefrom. These color parameters are: $x = .449$, $y = .408$. The present calibration of my radiometer yields color parameters for the standard lamp of $x = .447$, $y = .409$. Therefore, the change in temperature scale yields the following changes in color parameters: $\Delta x = +.002$, $\Delta y = -.001$. This deviation can be overcome by recalibration of the radiometer but this change would not appreciably alter the deviations between computed and measured color parameters for the fluorescent lamps reported in the Addendum hereto.

* National Bureau of Standards, Washington, D. C.

* Author

Lee Sock Store

This store formerly had a high ceiling, broken up by beams and many steam pipes. On the recommendation of the lighting consultant, the ceiling was lowered to 13 feet and made up of acoustical blocks, colored off-white. The rear of the store was composed of balcony for tailor, which was closed off by a mirrored wall giving appearance of greater depth.

The merchandising area of store is 14½ feet by 48 feet. The sidewalls were papered in pastel green with contrasting stripes. A light inlaid linoleum replaced former dark color. General illumination is provided by a mixture of fluorescent lighting units:

20 surface mounted fixtures with two continuous rows on 6½-foot centers.

12 recessed and louvered units spaced on 8-foot centers.

6 spot lighting units installed in continuous rows.

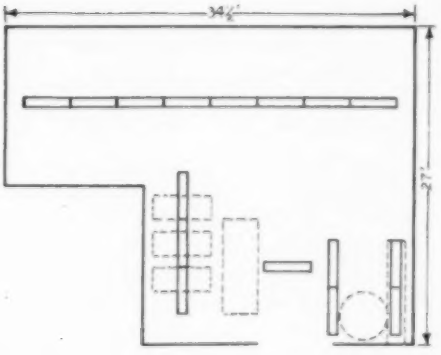
The lighting was supplemented by fluorescent wall case and show case lighting. The average illumination at the counter is 100 footcandles

Lighting data was submitted by R. H. Stewart, Lighting Division, Metropolitan Edison Co., Easton, Pa.

Lighting a Dairy

LIGHTING OBJECTIVE: To provide illumination in a fluid milk processing plant for pasteurization, homogenization, cooling, bottling, and inspection.

Installation at Green Glen Dairy, 30 Berry Street, San Francisco, California; lighting designed by A. C. Anderberg, Pacific Gas and Electric Company, San Francisco, California.



General Information: This 775 square foot area is finished as follows:

Ceiling	white	60% RF
Walls	white plaster	39% RF
	white tile	57% RF
Floor	red	8% RF
Machinery	stainless steel	65% RF

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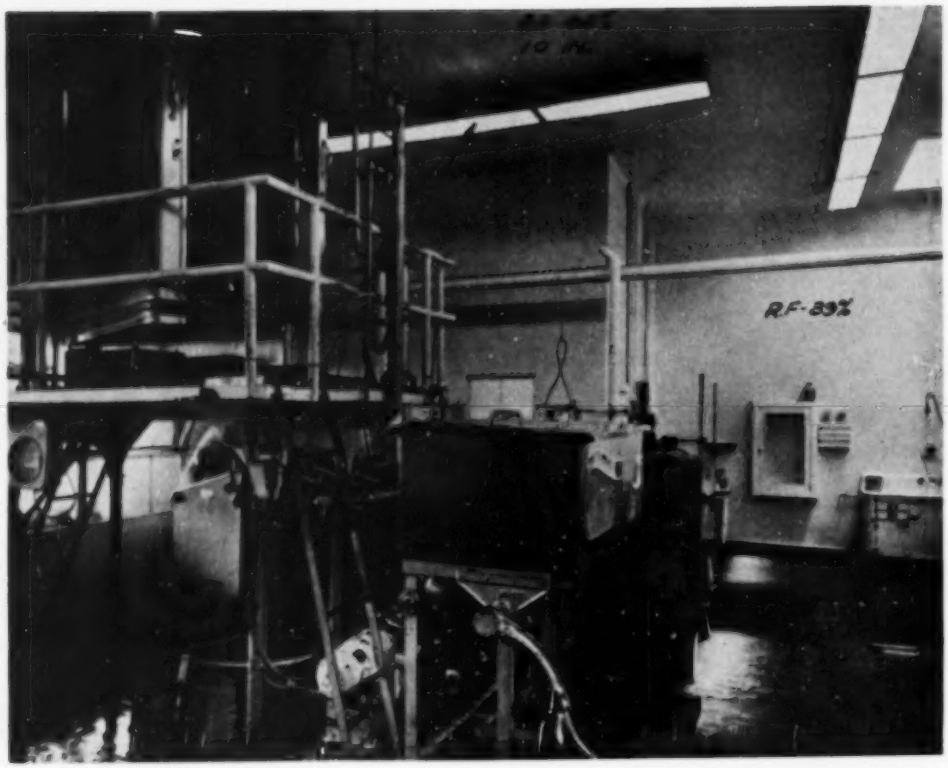

Installation: General illumination is provided by twelve vapor-tight luminaires (Benjamin Sealed Flo Vapor #48695 and #48680) each containing two 40-watt 48-inch T12 3500K fluorescent lamps mounted 14 feet 6 inches above the floor. Supplementary lighting for the bottling machine is supplied by four additional units of the same type mounted 8 feet 4 inches above the floor.

After almost four years of continuous operation the average general illumination on the working plane is 30 footcandles, with 55 footcandles at the bottling machine. Brightnesses are indicated on the photographs.

Lighting data submitted by A. C. Anderberg and S. E. Howatt, Pacific Gas and Electric Company, San Francisco, California, as an illustration of good lighting practice and to aid in the design of similar installations.

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Special Circuits for Fluorescent Lamps

By JOHN H. CAMPBELL

The fluorescent lamp, while appearing simple from the standpoint of the relatively few parts used in its assembly, is complex electrically. The variables involved in starting and operating the lamp invite development work not only in the design of the lamp itself but in the design of the required auxiliary equipment. This paper points out some of the unusual circuits for special applications and a few of the many possible ways in which the lamp may be started and operated.

THERE ARE innumerable circuits for starting and operating fluorescent lamps. It has been the author's experience to experiment with, test and develop nearly a hundred such circuits. This seemingly large quantity is probably small compared to the possible number of ways in which electric-discharge lamps can be operated.

In general, it can be said that the incentive for fluorescent circuit development stems from one or more of the following needs: (1) To obtain an advantage in starting or operating characteristics, (2) to reduce ballast size, (3) to simplify and lower the cost of fluorescent auxiliaries, and (4) to provide a means for operating fluorescent lamps in special applications where it is impractical to use conventional ballasts and circuits.

Many improvements have been made in lamps and ballasts since the introduction of fluorescent lighting. However, with very few exceptions, the circuits are unchanged. General-purpose circuits are the single lamp (low and high power factor), the split-phase two-lamp (preheat and instant start) and the sequence-start series circuit (14-, 85- and 100-watt). To those who are not thoroughly familiar with the problems of fluorescent-lamp development, it may seem strange that the activity in circuit development has not produced a greater change in the method of operating lamps for general use. Advantages of some of the experimental circuits include self-starting, simplicity, lower cost, and silent operation. However, in many cases, widespread use of these circuits must await lamp adaptation to retain or improve present values of life, lumen maintenance, and efficiency. It is easily understood that any marked reduction of these three factors as a result of the method of operation would make the circuit impractical for general use.

It is the purpose of this paper to describe fluorescent circuits for special applications and to point out a few of the many ways in which the lamp may be started and operated. In many cases, the type of power supply or special conditions of the application resulted in simplifying the circuit and reducing the initial cost of the lighting installation.

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: General Electric Company, Nela Park, Cleveland, Ohio.

Variable Frequency—Bus-Lighting Circuit

Fluorescent lighting has been used extensively in new railway cars and many of the lighting systems on old cars have been changed to fluorescent. The motor-coach lighting level has been increased considerably in the last few years due to improved filament lamps and fixtures. However, fluorescent lighting has been limited to a few motor coaches because of the difficulty of converting the 12-volt battery supply to the correct voltage and frequency. Most of the power supplies provided 60 cycles, so conventional ballasts could be employed. In this system, the converter obtained primary power directly from the main battery, the battery being charged by means of a d-c generator.

In recent years the load on the battery and generator has increased, requiring battery charging at idling speed, higher efficiency and higher output per pound of equipment. For these reasons and others which do not come within the scope of this paper, the direct-driven a-c generator has become increasingly popular with motor-coach operators. This system provides three-phase low-voltage variable-frequency power which is rectified for battery charging.

The a-c source provided a possible means for operating fluorescent lamps directly from the bus generator. However, at the time the first a-c generators were used, no circuit was available for controlling the fluorescent arc over a wide range of frequencies.

The frequency varies from 80 cycles at idling to

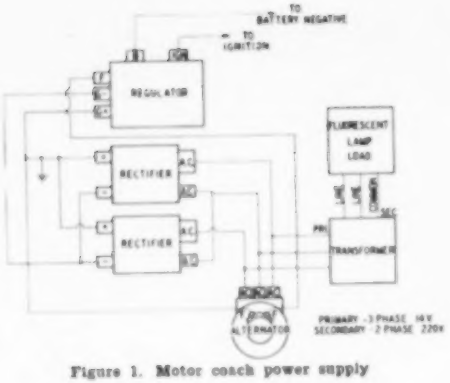

Figure 1. Motor coach power supply

500 cycles at full speed. The voltage is held to ± 10 per cent from design center by means of the voltage regulator. Fig. 1 illustrates the power-supply circuit.

The problems in the design of a circuit to regulate fluorescent-lamp current and light output over a wide range of frequencies were manifold. If the voltage of the generator was allowed to vary with the frequency, a self-compensating reactor ballast could be designed. However, the voltage would be excessive at high engine speeds and the ballast would be much larger than the conventional 60-cycle design. If a resistance ballast was employed, reasonable regulation could be obtained but it would be necessary to distribute 450 volts to start the lamp and the circuit efficiency would be extremely low. The problems were solved by arranging the proper values of inductive reactance, resistance and capacitance in a series parallel combination.

Fig. 2 shows the schematic diagram of the combination starting and ballast circuit. The 42-inch T-6 slimline lamp requires approximately 450 volts to start reliably, but since the optimum line voltage for regulation and efficiency is 220, another method of starting is employed. The 0.2 mfd. capacitor shown in shunt with the fluorescent and ballast lamp is tuned to near resonance with the choke coil at 400 cycles. The capacitor can be connected to either side of the ballast lamp, but the connection shown in Fig. 2 is preferred in order to obtain maximum voltage. During the starting period, the capacitor provides 450 volts. When the arc in the fluorescent lamp is established this voltage is reduced to a comparatively low value and the current taken by the capacitor is negligible. To obtain starting frequency, the motor-coach operator accelerates the engine to a speed corresponding to or greater than 400 cycles. After the lamps have started, they will remain on over the full frequency range. A larger capacitor could be employed to obtain the required starting voltage at frequencies corresponding to engine idling speed, but the current in the starting circuit at higher frequencies would be excessive.

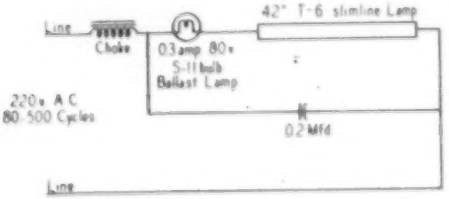

Figure 2. Variable frequency starting and operating circuit.

Ballast action is obtained by means of the series choke and ballast lamp. The choke is designed for the lowest impedance at the low frequency. The ballast lamp therefore provides the required resistance for current regulation. With increasing frequency, the choke-coil impedance and voltage increase and ballast lamp voltage decreases. For example, at 80 cycles the ballast lamp and choke coil have voltages of 80 and 50 respectively. At 500 cycles, the voltages are 40 and 190 respectively.

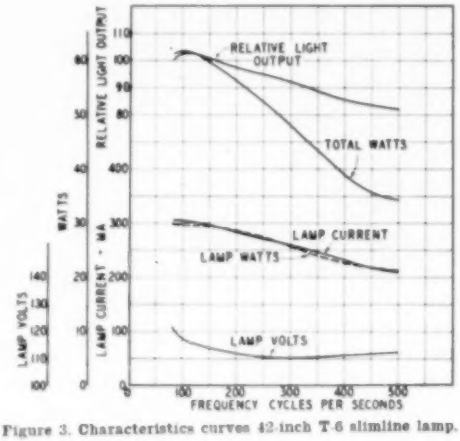

Figure 3. Characteristics curves 42-inch T-6 slimline lamp.

Fig. 3 shows the characteristic curves of the lamp and circuit with varying frequency. It will be noted that the lamp current and wattage drop approximately 27 per cent from 80 to 500 cycles while the light output drops 18 per cent over the same range. The comparatively low reduction in light output is due to an increase in lamp efficiency at the lower current loading. This effect is more pronounced at higher frequencies. The average light output occurs at approximately 300 cycles and varies ± 9 per cent

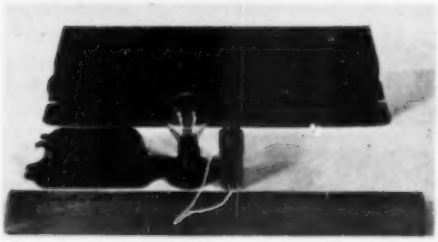

Figure 4. Size comparison—variable frequency ballast (foreground) vs. 60-cycle ballast.

at the low and high points of the frequency range. The change in light output at various engine speeds is not noticeable on the reading plane because of the time factor in reaching high and low speeds.

Some idea of the advantages of this circuit may be gained by looking at Fig. 4. The ballast components of the circuit are much smaller, weigh 85 per cent less and cost 75 per cent less than the conventional 60-cycle ballast.

The first trial installation was completed in a Chicago Motor Coach Company bus over a year ago with satisfactory results and others are now in service.

Capacitor Ballast for Aircraft

A paper[1] in the February, 1948 issue of ILLUMINATING ENGINEERING showed that capacitors could be used as ballasts for fluorescent lamps at frequencies above 300 cycles. While general use of higher frequencies still awaits an efficient and low-priced converter, there are a limited number of applications where high frequency is available. One such application is the commercial aircraft field where some 400-cycle power supplies are in use. The Boeing Airplane Company has included a comparatively large number of fluorescent lamps in lighting their new Stratocruiser.[2] Most of the Stratocruisers will use 30 fluorescent lamps, of which 19 are operated on capacitor ballasts. The additional 11 use the conventional choke-type ballasts in order to provide a high power factor load. The power supply consists of a 400-cycle, 208-volt generator with voltage regulation. Fig. 5 shows a schematic diagram of the capacitor-ballast circuit used to limit the current in 32-watt circline lamps and 30-watt straight lamps. The substitution of capacitors for the conventional choke-type ballasts saved approximately 21 pounds with the 400-cycle supply. The weight saved in ballasts alone would be 70 pounds if compared with a 60-cycle system.

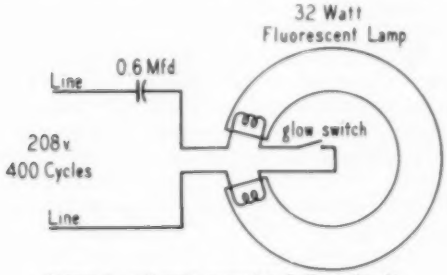

Figure 5. 400-cycle capacitor ballast circuit.

Sequence Starting

Weight and cost of ballasts can be materially reduced by starting lamps in sequence and operating them in series. A series circuit requires somewhat more time to maintain since both lamps go out when one fails, but there are many advantages for this method of operation worth consideration. The circuit was first applied to 14-watt lamps.[3] This lamp was originally designed for multiple operation on 60-volt, d-c train-lighting service. However, the voltage drop of the two lamps operating in series is about 80 volts which allows the use of a small filament lamp as ballast on conven-

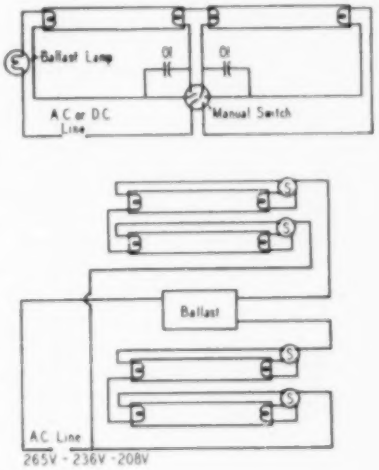

Figure 6 A. (Top) Sequence starting circuit resistance ballast. B. (Center) Sequence starting circuit split-phase ballast. C. (Bottom) Series operation—sequence resonant start.

tional 118-volt circuits. The ballast lamp provides excellent regulation of current over a wide range of line voltage and has the advantage of high power factor, silent operation and lower cost compared to the conventional choke-type ballast. The overall efficiency is lower than with the same lamps ballasted by means of chokes, but the efficiency is approximately double that of a filament lamp of equal light output. Fig. 6A illustrates the schematic diagram of the 14-watt circuit. Since the lamps start in sequence each receives approximately full line voltage in turn. The manual starting switch is designed for a mechanical delay between the opening of the two sets of contacts. The system as described has been used in floor, table and desk lamps.

Fig. 6B illustrates a sequence circuit for 100-watt lamps.[3] Ballasts of the split-phase type employing this circuit were used during the war to save copper and iron. Four lamps are operated from a ballast of approximately the same size and weight of the conventional two-lamp ballast. Additional advantages are the 50 per cent reduction in ballast price and watts loss per lamp.

The application of the sequence ballast for 100-watt lamps is limited to 265-volt distribution systems. It has been estimated that of the industrial power supplies in use at the present time, less than one per cent are 265 volts. The introduction of the 85-watt lamp has brought about reconsideration of the sequence circuit for possible use in large industrial plants. Since the 85-watt lamp contains krypton starting gas, the operating voltage is much lower than that of the argon filled 100-watt lamp. It is therefore possible to design a four-lamp sequence 85-watt circuit for the more common power systems such as 208, 220, and 236 volts.

Appraisal of the economics of the four-lamp ballast shows a decided advantage in the lower initial cost and energy savings inherent with this method of operation. However, the 85-watt sequence circuit requires a current-operated thermal starter and available starters of this type do not have the no-blink feature which is desired by some industrial users. The conventional no-blink glow-switch type will not operate satisfactorily two-in-series, on the lower voltage distribution systems. However, the obvious economic advantages of the sequence circuit will no doubt justify a careful analysis of the one disadvantage.

Resonant Sequence Start Circuit[3]

The sequence method of starting can be employed to start lamps quickly without the use of switches or preheat current. This is accomplished by shunting one of the lamps with a small reactor and capacitor as shown in Figure 6C. The two lamps are connected in series across a high reactance transformer with a capacitor for current control. Since excellent current regulation is obtained in a circuit of this type the open circuit voltage need be no greater than required to start one lamp. The lower lamp in Figure 6C starts first, and the current drawn by this lamp allows the shunting circuit to reach partial resonance, automatically producing sufficient voltage to start the top lamp. After starting, the two lamps operate in series. A circuit of this type can result in a ballast design of about half size when compared to the conventional instant start split phase circuit.

Since improvements have been made in the lamps themselves tests are now in progress to determine lamp life on this circuit.

Pulse Starting Circuits[4]

Before discussing a new starting method it may be well to review briefly some of the present systems.

Conventional methods for starting fluorescent lamps can be classified in two types, the preheat employing a starter, and the high-voltage instant start. Other less common methods are the previously described sequence circuit and the Resonant Sequence Start Circuit. Resonant circuits for multiple lamp operation while providing instant start at comparatively low line voltage require a multiplicity of chokes and capacitors. This results in a large, high-cost ballast for 60-cycle power. Less bulky resonant circuits may be used to advantage at higher frequencies or possibly in high-reactance high-voltage 60-cycle circuits.

When the preheat system is used, cathodes are prepared for starting by allowing sufficient current to flow through the electrodes to bring them up to emissive temperature. The starting switch then opens, applying full line voltage and an inductive "kick" between electrodes. In this system the line voltage or the secondary voltage of the ballast transformer must provide about double the lamp operating voltage. This added voltage is needed to start the lamp and to provide the necessary magnetizing current for the choke coil.

Instant starting by means of high voltage requires a transformer open circuit voltage or line voltage of from 2½ to 4 to 1 over lamp operating potential. The increase in voltage to start a lamp without preheat depends on the lamp length and diameter. For example, a 40-watt, 48-inch lamp requires approximately 4 times its operating potential while a 96-inch, T-8 lamp operating at 120 m.a. will start reliably at about 2½ times its operating voltage. When sufficient voltage is impressed be-

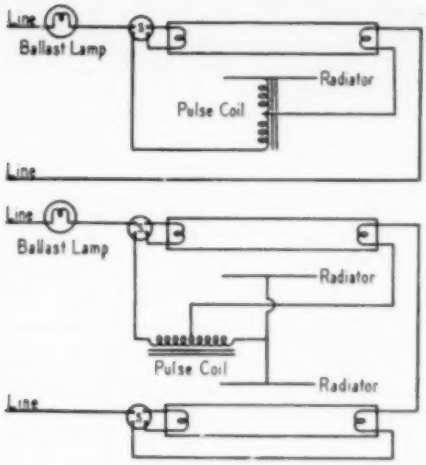

Figure 7 A. (Top) Pulse starting circuit single lamp. B. (Bottom) Pulse sequence starting circuit.

tween lamp electrodes, the starting gas ionizes, thus reducing the arc-path impedance. The full arc is established when electrodes are bombarded sufficiently to form the "hot spot" required to provide the necessary emission.

When lamp electrodes are preheated as in the case of switch starting, very little additional energy is required to start the lamp. An inductive "kick" at the opening of the starting switch is sufficient. However, since the conventional reactance ballast requires voltage for regulation during lamp operation, the voltage to start must be high compared to the lamp operating voltage. The watts loss and size of the ballast depends on the current required by the fluorescent lamp and the resulting K.V.A. in the ballast. It is well known that a resistance can be used as a ballast for fluorescent lamps. A tungsten-filament resistance ballast lamp provides excellent regulation, silent operation and high power factor. The use of this system of current control has been limited to d-c operation, or to small lamps operating on the sequence circuit. The limited use logically stems from the fact that at the voltage required to start the fluorescent lamp, the watts lost in the resistance is considerably greater than a reactance ballast, thus making the overall efficiency lower. Since a tungsten filament ballast has a positive resistance coefficient, it can be designed to operate with a very small difference between lamp and line voltage. It therefore follows that if starting can be accomplished at the low voltage, the watts loss in the ballast lamp will be comparable to the reactance ballast.

Fig. 7A illustrates a low energy pulse starting circuit in which the fluorescent lamp is made to start and operate within a few volts of the lamp operating potential. The pulse coil is a small autotransformer with a high turn ratio similar to the ignition coils used in model airplanes. Satisfactory pulse coils have been made with dimensions of only $\frac{1}{8}$-inch in diameter and $2\frac{5}{8}$-inch long. The ballast lamp can be of small size and the starter of the current-operated thermal type. The auxiliary electrode or radiator is a small piece of metal arranged to contact the tube externally at the middle of its length or located in close proximity to the bulb.

When line voltage is applied, the lamp electrodes receive preheat current and the primary of the pulse coil is energized. When the starting switch opens, a high-voltage low-current pulse with a high-frequency component is generated by the secondary of the pulse coil. This energy is radiated to the lamp by means of capacitance coupling between the auxiliary electrode and the bulb wall and dissipation of the energy in the pulse results in ionization of the starting gas. With the gas ionized, the impedance of the arc path is reduced sufficiently to cause the lamp to start at the applied voltage. The pulse coil is then removed electrically from the circuit with the opening of the starting switch. Current regulation with normal variation in line voltage is accomplished automatically by a corresponding change in the resistance of the ballast lamp.

Fig. 7B illustrates a sequence pulse-starting circuit where one ballast lamp and one pulse coil serve two lamps. In some applications where it is desirable to supplement fluorescent lighting with filament downlighting, it may be possible to operate the ballast lamp at full rating and utilize this source for both illumination and ballast.

Provision for future use of circuits such as switch-type pulse starting depends upon solving many problems in the design and manufacture of fluorescent lamps.

Acknowledgements

The author wishes to express his thanks to Mr. Emery Szabo, of the Leece Neville Company, Cleveland, Ohio, for furnishing the power supply diagram and the generator data used in designing the variable frequency motor coach circuit.

Comprehensive laboratory and field tests were needed to establish design features for the various circuit components of the motor coach circuit. The author wishes to acknowledge his appreciation to R. R. Marvin, M. A. Mortensen, H. E. Schultz and D. D. Kershaw, of the Engineering Division, Nela Park for their contributions and keen interest.

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DISCUSSION

F. J. VORLANDER*: It is interesting to note that since the author presented a preliminary paper which dealt with high frequency operation of fluorescent lamps two years ago, this system has been placed in operation in buses with satisfactory results as anticipated. High frequency operation seems particularly well adapted to lighting buses and airplanes. I wonder if it would also be an economical installation in trains and rapid transit street railway lines where alternator speed up may be practical, but where it may be more difficult to obtain the frequency control desirable for satisfactory lamp starting and minimum weight and costs.

There are obvious advantages of high frequency operation for buses and airplanes in that radio interference will be less than with 60-cycle supply. This may be of particular value in view of the increasing tendency to place radio installations in motor coaches. Another advantage should be the reduction of stroboscopic effect at such frequencies as 80 to 500 cycles.

It is not quite clear in the paper whether the engine of the motor coach generator must be speeded up so that the frequency will be increased to approximately 400 cycles to attain 450 volts for starting or whether the voltage is already close to that at the lower frequencies and engine speeds.

It would be interesting and it is important to know the effect on life and lumen maintenance resulting from operation on the variable frequency circuit discussed.

Sequence starting, while it has a definite advantage in lower installation cost, will most certainly have higher maintenance costs and with today's high cost of labor, it is probably more costly throughout the life of the installation than conventional multiple circuit operation.

Pulse starting also has definite advantages, but it does have the disadvantages of the need for modifications in fixtures to accommodate the circuit and the need for training maintenance personnel in handling such equipment. With present day emphasis on instant starting lamps and fixtures, it would appear that the sequence starting and pulse starting methods would be interesting methods of starting fluorescent lamps but hardly those which we can expect manufacturers to adopt.

It does appear that high frequency operation has definite advantages which may eventually lead to more extensive use of this method of control for instant start equipment. Work of this nature, although some of it may appear to be of little commercial nature at present, is really the basis of engineering development which leads to future improvements and because of this is really worthwhile.

J. H. CAMPBELL*: I believe Mr. Vorlander poses some fair questions regarding the various circuits discussed in my paper.

High frequency power supplies for railway lighting as a possibility have not been overlooked, but acceptance by American Railways depends upon solving many problems not encountered in bus lighting. A direct driven generator cannot be used for power since it is in operation only when the train is in motion. Batteries are the primary source of power and a motor generator set can be used to provide high frequencies rather than the present accepted 60-cycle conversion. However, the relatively high speeds required to obtain 400 cycles may increase maintenance of the power supply. Also, some cars are equipped with a plug-in device to provide 60-cycle power to the train while standing as a means of saving the batteries. Apparently these complications do not exist to so great an extent in Europe since many railway cars there are equipped with 400-cycle power supplies for fluorescent lighting.

It is quite true that radio interference will be somewhat less due to operation of fluorescent lamps at higher frequencies. However, this is a minor point compared to the main advantages such as lower ballast cost, and less ballast weight. Insofar as bus lighting is concerned, it gives the bus manufacturers an opportunity to install fluorescent lighting without resorting to separate converters for the lighting system alone.

Regarding the method used to obtain 450 volts for starting, the paper points out that the engine speed must be increased to a point where 400 cycles is obtained. At this frequency the capacitor is in partial resonance with the choke coil and 450 volts appears across the lamp for starting. After starting, the voltage of the capacitor becomes essentially that of the fluorescent lamp. One of the reasons that the ballast can be made so small for this system is that it is necessary to distribute only 220 volts which is the voltage required for proper current regulation over the frequency range. Regarding the life and lumen maintenance resulting from operation on the variable frequency circuit, it is impractical if not impossible to duplicate the bus condition in the laboratory. For that reason, life tests have been made in actual buses over a period of two years. At the present writing, it appears that the life of lamps on the variable frequency system will be the same as for 60 cycles.

I assume that Mr. Vorlander was referring to the sequence start four-lamp, 100-85-watt ballasts when he referred to sequence starting. It is true that maintaining a series system may require somewhat more time than a multiple system. However, economic studies indicate that large industrial installations where this circuit is employed have a much lower intitial and energy cost with this circuit than with the two-lamp ballast. The savings in energy cost alone may be sufficient in most cases to more than overcome the extra maintenance cost.

*Champion Lamp Works, Lynn, Mass.

*Author.

Pulse starting presents some interesting possibilities in simplifying present circuits as well as reducing size, weight and cost of ballasts. However, as pointed out in the paper, general use of this system depends upon the desirability and success of lamp adaptation to obtain the described advantages. The change in fixtures to accommodate the small contact or radiator is a minor problem. There are no reasons why maintenance personnel would need special training to handle fixtures of this type. Possibly Mr. Vorlander had in mind shock hazard as a result of the pulse coil action. The contact transfers the low energy of the pulse coil to the lamp by means of capacitance and can therefore be adequately insulated.

Application of Recommended Brightness Limitations to School Rooms*

By F. C. Winkler and John J. Neidhart

DISCUSSION

HAROLD B. GORES**: I take exception to the following statement which appears in the paper "Application of Recommended Brightness Limitations to School Rooms" by Winkler and Neidhart, (December, 1949):

"Many school officials feel, however, that the advantage of increased comfort provided by such an installation (translucent plastic bottom) is more than offset by its higher cost, lower illumination level, and a greatly increased maintenance problem. A closed bottom luminaire is particularly troublesome in school classrooms where children are prone to toss paper wads, clips, etc., into the luminaire. Louvered bottoms will normally allow such extraneous matter to fall through unless the louver cells are too small to permit passage."

I do not dispute the authors' assertion that "many" school officials hold these things to be true for I cannot prove that all do not. My concern with the statement is that the casual reader may assume two things:

1. That "many" may mean "all" or even "most" school officials; and
2. That the arguments are true and compelling.

May I examine the arguments in the order in which they were presented:

1. *"It is more expensive."* This argument may also be used to make a case for outdoor plumbing. Cost should be a critical factor only when increased costs do not yield corresponding increase of benefits. The emerging research, as far as I know, and the conclusions of the Winkler-Neidhart paper itself are compelling evidence of increased benefits commensurate with increased costs.
2. *"Lower illumination level."* If the proof of the purchase is the amount of raw light produced, there is no dispute. If, however, the objective is optimum seeing conditions the objection disappears and becomes a function of the cost factor.
3. *"Greatly increased maintenance problem."* To be sure, it costs more to maintain something than not to maintain it. The whole visual surround of the classroom needs to be maintained. Compared with cost of maintaining the ceilings, walls, floors, and other surfaces of the classroom environment, the cost of cleaning the luminous shields is negligible. The cost of maintaining luminous indirect fixtures looms large only if it is the only maintenance that is being done. Further, there is good reason to believe that if nothing else in the room is going to be maintained as the total environment deteriorates, the careful maintenance of only one factor, the lighting fixture, may very well introduce severe unbalance.
4. *"Children toss paper wads, clips, etc. into the luminaire."* This is a problem of human, rather than electrical engineering. By the same token one might argue that a school lunch program is bad because the children may scale the milk bottle tops around the room. Children engaged in an active and meaningful program of education in the classroom have no awareness of the light source. This observation is based upon three years' experience with more than 2000 luminous indirect fixtures in classrooms. The fact that "louvered bottoms will normally allow such extraneous matter to fall through" is scant solution to the problem of finding something more useful for the children to be doing.

JOHN J. NEIDHART AND F. C. WINKLER*: The authors offer their apologies to Mr. Gores if he believes that we have sold quality lighting down the river. We certainly did not intend to imply that we do not like or recommend semi-indirect installations. There is no question but that semi-indirect lighting provides a high degree of seeing comfort up to levels of about 50 footcandles. At higher intensities, the ceiling brightness is apt to be objectionable with such installations.

We note that Mr. Gores agrees with our statement that "many school officials feel, however, that . . . ." We did not say *all* school officials or even *most* school officials. The meanings of the words "many" and "all" and "most" are well established in the English language and should be easily understood by even the casual reader.

The facts remain that semi-indirect lighting is more expensive since more luminaires are required to produce a given intensity (or a lower intensity will prevail) and the maintenance problem is greatly increased. The maintenance problem is perhaps the biggest obstacle. Granting that the cost of maintaining room surfaces is much greater, Mr. Gores must admit that these surfaces may be restored much less frequently than will the lighting equipment. Luminaires having closed bottoms and open tops accumulate dust and dirt at a very rapid rate, because there is no alternative but for the dirt to fall and remain on the bottom panel. The authors have talked to *many* (not all or most) school officials who are strong advocates of good classroom lighting but who are nevertheless not prepared to shoulder the expense of maintaining semi-indirect luminaires. We think that their attitude may be summed up to the simple fact that they would prefer semi-indirect lighting (as they would prefer many other deluxe items) but they lack the funds to purchase and maintain such equipment. Perhaps they could light a few of their classrooms by the "preferred method" but they would rather provide just plain good lighting in more rooms, thus benefiting more children.

*ILLUMINATING ENGINEERING, December, 1949, page 732.
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*Authors.

Lighting and Seeing Conditions for Hand Sewing in the Home

By MYRTLE FAHSBENDER and PRISCILLA PRESBREY

This paper is a study of (1) the lighting conditions most desirable for hand sewing in the home and (2) the types of available equipment which will most nearly provide these conditions. Sixteen luminaires are appraised on the basis of their ability to produce satisfactory lighting for hand sewing.

SEWING, involving as it often does small visual objects and low degrees of contrast, is recognized as a difficult visual task. It requires possibly the best and most carefully applied lighting of any work that is commonly done in the home. And yet little specific attention has been given to this problem, beyond the Illuminating Engineering Society's recommendation of 20 footcandles for "periodic average sewing," 40 footcandles for "prolonged average sewing," and 100 or more footcandles for "sewing on dark goods, fine needlework."[1] This study was undertaken with the purpose, first, of investigating the lighting conditions most satisfactory for hand sewing in the home, and then of determining to what extent these conditions can be provided by common types of available home lighting equipment. The two phases of the project are reported separately.

Part I Preliminary Observations

The approach to a problem of this nature is facilitated by the compilation of certain background information which might well be classified as "experience." For this purpose a questionnaire on sewing habits, including lighting, was prepared and mailed to a selected list of women. A detailed report on the more than 300 replies received does not come within the scope of this paper, but it is of interest here to note that a surprisingly large number of the women who replied were conscious of the importance of lighting for sewing. A great many reported that they sewed in the daytime because they did not have adequate artificial light, and the choice of the room for evening sewing was to a large degree dependent on the lighting. At least a third of the replies indicated dissatisfaction with the present lighting.

It is obvious at once that the general term "sewing" includes a large number of different visual tasks. To mention but a few, sewing may be taking large stitches with thread of a contrasting color, as in basting, or taking very fine stitches with matching thread; it may be taking stitches on a flat surface of the material, or at the edge of a fold, as in hemming; it may be a difficult weaving process, as in darning socks or mending; or it may be a matter of filling in one stitch next to another, as in embroidery and needlepoint. In addition, types of fabrics vary tremendously: light or dark, figured or plain, dull-surfaced or shiny, coarse or fine weave, transparent or opaque, smooth or textured. Thread, also, is of different sizes, materials, and finishes.

So wide a range of conditions, of course, results in an equally wide range of relative visibilities, extending to very low levels at customary illumination values. The diameter of a No. 50 cotton thread, for example, is approximately 0.009 inch, which at a distance of 14 inches from the eyes subtends an angle of about 2 minutes. According to published tables,[2] a 2-minute critical detail with a contrast of five per cent requires a brightness of 240 footlamberts to achieve a visibility-level of 1. On this basis, if a fabric has a reflectance of five per cent, an illumination of 4800 footcandles would be necessary to provide even threshold visibility for a detail of that size and contrast — that is, to make it barely visible to a normal eye. The diameter of a single thread is probably a smaller object than it is often necessary to see, but even a $\frac{1}{8}$-inch stitch, which subtends a lengthwise angle of 15 minutes, under similar contrast conditions theoretically requires a brightness of 1.3 footlamberts, or 26 footcandles on a five per cent reflecting surface, for threshold visibility, and 1280 footcandles for a visibility-level of 4, which is regarded as a conservative visual "factor of safety."

However, calculations such as these are based on a visual task like reading, where the detail to be seen is on the same plane as the background (*i.e.*,

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ink printed on paper), and disregard the effect which direction of light can have in helping or hindering the visibility of a more complicated seeing process such as sewing. Measurements of actual visibility-levels of sewing tasks therefore seemed likely to be productive of interesting and instructive results.

Test Procedure

For the purpose of this study, it was necessary to select some one simple sewing task which could be used as a standard. Five materials were chosen: a plain, matte-finished, closely woven, smooth, white cotton, a similar material in a medium gray, a slightly finer weave in a black matte-finished cotton, and a white and a black rayon satin. Total reflectance measurements made with a sphere reflectometer gave the following results:

White cotton	65% reflectance
Gray cotton	17%
Black cotton	2%
White satin	67%
Black satin	4%

The thread used was No. 50 matching cotton on the cotton fabrics, and matching silk on the satins. The visual task selected was the ability to see, and to follow, a short section of plain running stitch, with stitches $\frac{1}{8}$-inch long, on each of these materials. This admittedly very limited number of fabrics and conditions does at least include a wide range of reflectances and degrees of specularity.

A Luckiesh-Moss visibility meter was used to take readings on these five samples under 10, 20, 40 and 80 footcandles of totally direct light, totally indirect light, and a fifty-fifty combination of the two. All the light sources used were incandescent, the direct component being provided by a bare inside frosted lamp placed slightly above, to the side of, and behind the test plane. The readings were made in a standard I.E.S. test room.[3] The meter was so located that the observer's eyes were 14 inches from the task, and the field of view was reduced by a hood to approximately 10° vertically and 10° horizontally. A sample of 8-point Bodoni Book type, printed in black ink on white paper, was included in each set of readings as a check on the individual's use of the meter.

Conclusions

The use of the visibility meter demonstrated that the chief factors enabling the eye to see a stitch against its background, in the absence of color contrast, are differences in the specularly reflected light reaching the eye from the thread and from the cloth, and minute shadows cast by the thread and by slight ridges resulting from the tension of the stitches. Specular reflection was, of course, most marked with the satin fabrics and direct light, but it also proved to be present to a slight but significant degree with the dull-finished cotton fabrics and cotton thread, even when the light was totally

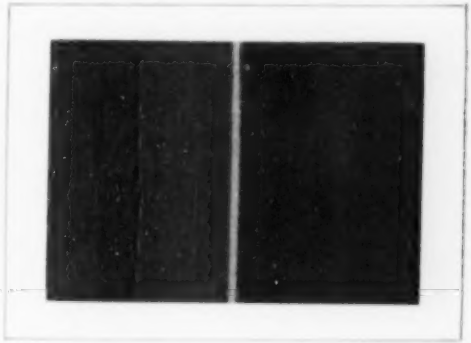


Figure 1. A line of stitches on the gray cotton test fabric, lighted by approximately equal footcandles of direct light (left) and totally indirect light (right). The difference in relative visibility is apparent.

indirect and the source was the ceiling. Specular reflection from the surface of the cloth is, of course, determined by the angular relationships between the light source, the work surface, and the eye, but because thread is round, there is nearly always some specular reflection from some part of it.

In general, specular reflection from the material was found to be a hindrance to visibility, and specular reflection from the thread helpful. For the satins, where specular reflection is high, this meant that the more diffuse the light the more satisfactory the seeing conditions, and that the indirect light was the most desirable. For the cottons, on the other hand, the situation was different. Here the specular reflection from the cloth was so comparatively small, and the highlight on the thread and the tiny shadows so important to the seeing process, that under totally indirect light the working field appeared unnaturally flat, and the line of stitches was difficult to see. Thus it was obvious that the visibility-levels of the test tasks could not be specified in terms of footcandles alone. It was quite possible that a relatively low value of illumination properly directed, could give a task the same visibility-level as a greater quantity of light, less effectively directed.

It must be admitted that these conclusions are based largely on observations, rather than on test results. The actual visibility measurements, un-

fortunately, were not sufficiently consistent to supply statistical proof of conditions which were clearly apparent to the observers. Although the data showed some indication of the advantages of a directional component in raising the visibility-levels of the dull-finished materials, the readings in themselves were not precise enough to warrant any definite conclusions. One reason for this was the difficulty of maintaining from test to test a fixed standard of what constituted "seeing" the test stitches. The chief cause of uncertainty in the readings, however, was undoubtedly the fact that the relative positions of the source of direct light, the test surface, and the eye, were so extremely critical. An exceedingly small change in any one of these could greatly alter the appearance of the stitches, and under the conditions of the tests it was almost impossible to maintain the precise dimensions necessary for exact duplication of readings. Moreover, the most favorable light-source location for the dull-surfaced fabrics was not necessarily the same as for the shiny ones.

Furthermore, although for the satins the totally indirect light provided the most comfortable conditions for sewing, it was possible with direct light to silhouette the stitches against a very bright background in a way that would give a higher visibility-meter reading, with less comfortable seeing conditions. For these reasons, and others, the visibility meter was difficult to use with precision under the existing test conditions, and the measurements were not successful as a means of comparing the effectiveness of various types of lighting.

However, it was not difficult to assign relative visibility-levels to the five test tasks under totally indirect light. At 10 footcandles, totally indirect, the stitches on the white satin had a visibility-level of approximately 3.0, those on the white cotton approximately 2.5, the gray cotton approximately 2.0, and the black satin approximately 1.5. The stitches on the black cotton were below threshold visibility at 10 footcandles, but at 20 footcandles had a visibility-level of about 1.5. A visibility-level of 4, representing a task of nearly the same difficulty as reading 8-point type under 10 footcandles, is surely about the lower limit at which most people would wish to sew for any length of time. To attain even this visibility-level, on the basis of the normal ratios to be expected between visibility and illumination,[4] would require for the white satin at least 20 footcandles, for the white cotton at least 35, for the gray cotton 65, for the black satin 250, and for the black cotton 500. The curves of illumination *vs.* measured visibility-level, for indirect light up to 80 footcandles, agreed reasonably well with these figures.

Required footcandles for a given visibility-level calculated from object-size and a nearly zero brightness contrast (which would exist when the thread matched the fabric, if the light were completely diffuse and specular reflection entirely absent), would of course be considerably higher than the values listed above. The presence of highlights and shadows, even with indirect light, reduces the required footcandles below the theoretical values, and partly or completely directional light changes them further.

The five test tasks were very limited in their scope as compared with the enormous variety of possible kinds of sewing. However, they are perhaps representative of common, simple sewing on light, medium, and dark smooth-finished fabrics, and the footcandles reported provide some indication of the amount of light necessary for the comfortable performance of similar tasks.

Part II — Test Procedure

The foregoing tests and observations, together with the accepted principles of good lighting practice, indicate that the most satisfactory lighting installation for sewing is one that provides (1) as high a footcandle level on the work as practicable, (2) at least some direct component, (3) sufficient general room illumination to create a comfortable surround, and (4) freedom from glare sources in the visual field. The question of light-source color, which in itself presents a complicated problem, has been disregarded.

The results of the authors' questionnaire show that sewing is done in almost every room in the home, including the hall. Living room, bedroom and dining room were the three rooms most often used, and the lighting was almost exclusively from floor and table lamps, either alone or in combination with a ceiling fixture. Because portable lamps or other local lighting equipment offer the most practical means of providing high footcandle levels, the majority of the luminaires selected for test were portable lamps. Reflector and projector lamps mounted in the ceiling over the work area were also tested.

All of the test equipment was incandescent except two portables which combined fluorescent and incandescent. Although for best seeing conditions it is almost always necessary to add other illumination to a local light source, in order to determine the performance of the individual luminaires it was necessary to test them without the presence of other illumination.

Selection of Test Plane: In order to make possible an effective comparison of the various luminaires, some definite test area on which illumination mea-

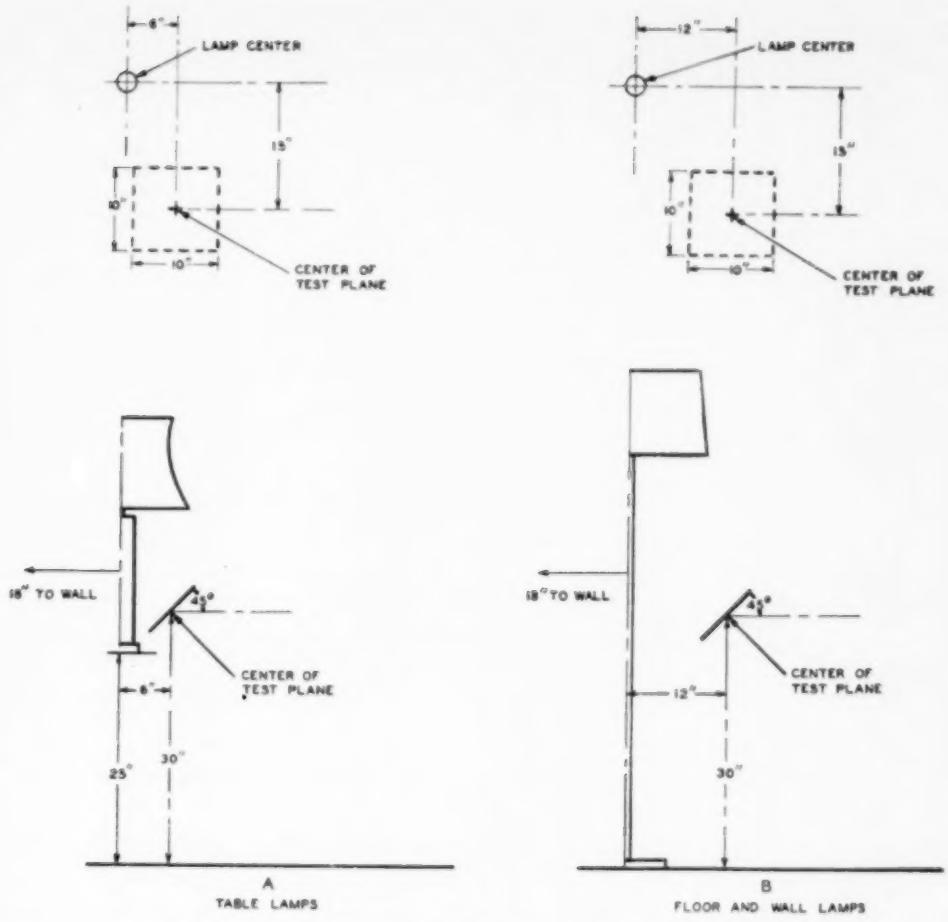
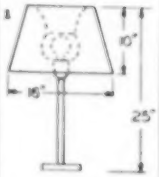
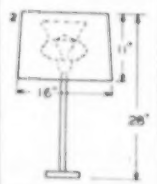
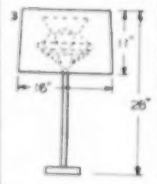
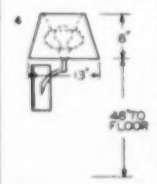


Figure 2. Positions of test plane used with Certified lamps. Exceptions are noted in Table I.

surements could be made had to be selected. "Lighting Performance Recommendations for Portable and Installed Residence Luminaires"[2] establishes for hand sewing a test plane 10 by 10 inches tilted back 45° from the vertical, with its center 26 inches above the floor. The dimensions of the test plane and the angle of tilt seemed satisfactory, but a consideration of the wide range of furniture dimensions, and actual measurements of the sewing habits of a number of individuals, led the authors to question the 26-inch height.

The average seated eye height of women has been reported[5] as 30 inches, plus or minus three inches. Measurements showed that most women, when sewing, assume a position which lowers their eyes approximately four inches from the erect position. Also, when the work is held 14 inches from the eyes it is only about 12 inches below them on a vertical line. If the subject holds her sewing on her knee, as many women do, the position of the work is further lowered. The seat height for unupholstered chairs is usually 17 to 18 inches, while upholstered chairs or sofas are commonly lower, with some modern designs as low as 12 inches. Considering all these variables — seated eye heights, furniture dimensions, and sewing habits — it is obvious that the height at which the work is held will change greatly with the individual and with circumstances. For example, a short woman on a 12-inch davenport will hold her work about 23 inches from the

TABLE I—Performance of Test Luminaires

Luminaire	Description	Position of Luminaire With Respect to Center of Test Plane[1]	Footcandles on Test Plane Average (Min. to Max.)	Ratio of Direct to Indirect Illumination on Test Plane Average	General Room Illumination Average Footcandles (Approx.)	Brightness of Opposite Wall Footlamberts (Approx.)	Brightness of Floor Within Visual Field Footlamberts (Approx.)	Comments
1 	CLM Table Lamp Type C Reflector 50-100-150 W Opaque Shade	Center of light source 15" to side and 6" behind test plane center. (Fig. 2-A)	43 (29-60)	93:7	3	1.2	1 to 2.5	Quantity satisfactory for light-colored fabrics; inadequate for prolonged sewing, dark fabrics, fine detail. Quality satisfactory. Under-shade brightness completely shielded in either sewing or relaxed[2] position.
2 	CLM Table Lamp Type B Reflector 50-100-150 W Opaque Shade	Center of light source 15" to side and 6" behind test plane center. (Fig. 2-A)	35 (24-48)	86:14	3	1.5	1 to 2	More light desirable even for light-colored fabrics. Quality satisfactory. Under-shade brightness completely shielded in either sewing or relaxed[2] position.
3 	CLM Table Lamp Type B Reflector 50-100-150 W and 32 W Fluorescent Opaque Shade	Center of light source 15" to side and 6" behind test plane center. (Fig. 2-A)	70 (43-93)	84:16	6	2.5	2 to 5	Quantity satisfactory for many sewing tasks; higher footcandles necessary for dark fabrics, fine detail. Quality satisfactory. Under-shade brightness completely shielded in either sewing or relaxed[2] position.
4 	CLM Wall Lamp Type B Reflector 50-100-150 W Opaque Shade	Center of light source 7¾" from wall, 15" to side and 12" behind test plane center. Bottom of shade 48" from floor.	32 (27-38)	75:25	3	1.3	1 to 2.5	More light desirable even for light-colored fabrics. Quality satisfactory. Under-shade brightness annoying when in relaxed[2] position.

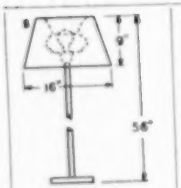
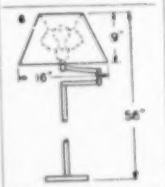
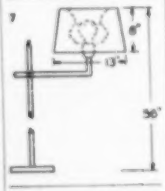
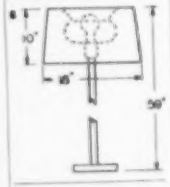
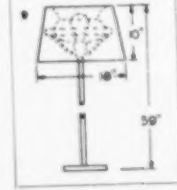
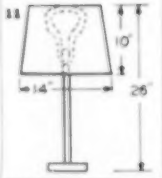
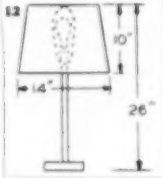
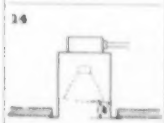
	CLM Jr. Floor Lamp Type B Reflector 50-100-150 W Translucent Shade	Center of light source 15" to side and 12" behind test plane center. (Fig. 2-B)	30 (26-36)	80:20	4	1.5	2 to 3	More light desirable even for light-colored fabrics. Quality satisfactory. Observer conscious of under-shade brightness in sewing position; brightness of translucent shade less annoying than opaque shade.
	CLM Swing-Arm Bridge Lamp Type B Reflector 50-100-150 W Translucent Shade	Center of light source 15" to side and 2" behind test plane center.	32 (24-44)	81:19	4	1.5	2 to 3	More light desirable even for light-colored fabrics. Quality satisfactory. Observer conscious of under-shade brightness in both sewing and relaxed[3] positions.
	CLM Bridge Lamp Type B Reflector 50-100-150 W Opaque Shade	Center of light source 15" to side and 2" behind test plane center.	37 (28-51)	84:16	4	1.5	2 to 3	More light desirable even for light-colored fabrics. Quality satisfactory. Observer conscious of under-shade brightness in sewing position; brightness annoying in relaxed[3] position.
	CLM Sr. Floor Lamp 100-200-300 W Type A Reflector Opaque Shade	Center of light source 15" to side and 12" behind test plane center. (Fig. 2-B)	65 (56-76)	83:17	11	3.0	3.5 to 6	Quantity satisfactory for many sewing tasks; higher footcandles necessary for dark fabrics, fine detail. Observer conscious of under-shade brightness in sewing position; brightness annoying in relaxed[3] position.
	CLM Sr. Floor Lamp 100-200-300 W and 32 W Flu. Type A Reflector Opaque Shade	Center of light source 15" to side and 12" behind test plane center. (Fig. 2-B)	100 (85-119)	88:12	15	4.0	4.5 to 9	Quantity satisfactory for many sewing tasks; higher footcandles desirable for dark fabrics, fine detail. Quality satisfactory. Observer conscious of under-shade brightness in sewing position; brightness annoying in relaxed[3] position.

TABLE I.—Performance of Test Luminaires (Continued)

Luminaire	Description	Position of Luminaire With Respect to Center of Test Plane[1]	Footcandles on Test Plane Average (Min. to Max.)	Ratio of Direct to Indirect Illumination on Test Plane Average	General Room Illumination Average Footcandles (Approx.)	Brightness of Opposite Wall Footlamberts (Approx.)	Brightness of Floor Within Visual Field Footlamberts (Approx.)	Comments
10	Totally Direct Type Lamp 100 W Metal Reflector, Adjustable Shaft, and Swing Arm	Center of light source 10" to side and 2" behind test plane center.	43 (30-64)	Indirect component negligible	0.5	0.3	1 to 1.5	Quantity satisfactory for light-colored fabrics; inadequate for dark fabrics, fine detail. Source brightness completely shielded from view. Some increase in footcandles obtainable by lowering light source.
11 	Table Lamp 150 W R-40 White Indirect Lite Opaque Shade	Center of light source 15" to side and 6" behind test plane center. (Fig. 2-A)	49 (30-71)	88 : 12	4	1.8	1 to 3	Quantity satisfactory for light-colored fabrics; inadequate for prolonged sewing, dark fabrics, fine detail. Quality satisfactory. Under-shade brightness completely shielded in either sewing or relaxed[2] position.
12 	Table Lamp 100 W Opaque Shade	Center of light source 15" to side and 6" behind test plane center. (Fig. 2-A)	39 (25-57)	92 : 8	2	1.2	1 to 2	More light desirable even for light-colored fabrics; inadequate for prolonged sewing, dark fabrics, fine detail. Lamp possible source of annoying specular reflection under some conditions. Under-shade brightness completely shielded.
13	150 W R-40 Flood Recessed in Ceiling	Light source centered laterally over test plane, 4" behind test plane center.	21 (20-22)	81 : 19	5	1.0	1 to 3	Footcandles from flood lamp inadequate; from spot lamp good. With spot lamp specular reflection from needle and thimble annoying. Observer conscious of overhead brightness when in relaxed[2] position.
	150 W R-40 Spot Recessed in Ceiling		117 (110-122)	96 : 4	5	1.0	1 to 10	
14 	150 W PAR-38 Flood Recessed in Ceiling	Light source centered laterally over test plane, 4" behind test plane center.	48 (43-52)	89 : 11	5	1.0	1 to 7	Footcandles from flood lamp fair; from spot excellent. Specular reflection from needle and thimble excessive. Specular reflection from shiny fabrics annoying. Observer bothered by overhead brightness when in relaxed[2] position.
	150 W PAR-38 Spot Recessed in Ceiling		200 (173-227)	97 : 3	4	1.0	1 to 20	

[1]All table lamps tested on 25-inch table. (See Fig. 2-A). Center of light source 18 inches from wall except where noted.
[2]Eyes directed horizontally straight ahead.

floor, whereas a tall woman on an 18-inch chair will work about 35 inches above the floor. From this range (and a still wider range is possible) a distance of 30 inches from the floor to the center of the test plane was selected as a reasonable working average. (See Fig. 2.) The 14-inch distance from the eyes to the center of the test plane was maintained.

Placement of Luminaires: Certified lamps are tested for the illumination they produce on a reading plane 26 inches above the floor. Table lamps are placed on a 25-inch table, the center of the light source 16 inches behind and 20 inches to the side of the center of the test plane. With floor models the center of the light source is placed 26 inches behind and 15 inches to the side of the center of the test plane.

In the interest of obtaining higher footcandle values for sewing, it seemed desirable to place the lamps closer to the test plane. After some experimentation and measurement, it was decided that the dimensions shown in Fig. 2 located the lamps as close to the work as possible while still avoiding annoying brightness and too close proximity to the shade. With a few of the floor lamp models this location resulted in some degree of discomfort from under-shade brightness when the eyes were raised from the work. However, the authors felt that the higher footcandle levels resulting from the closer positioning more than compensated for this unpleasantness at occasional moments of relaxation. These dimensions were used for all portable lamps except Tests No. 6, 7, and 10 (Table I). Because of the construction of these three lamps, it was possible to obtain more light by bringing the source still closer to the test plane.

Reflector and projector lamps were recessed in the ceiling four inches behind the test-plane center and 1¾ inches above the ceiling line. See Tests No. 13 and 14 in Table I.

All portable lamps were tested with the light-source center 18 inches from the center of one wall of the test room. The test plane was parallel to the wall. See Fig. 2.

Measurements: All illumination measurements were made in a standard test room[3] 12 feet square with an 8 ft 6 inch ceiling. The ceiling had a reflectance of approximately 75 per cent, the walls 50 per cent and the floor 20 per cent.

Footcandle measurements were made in the center of the test plane and in each of the four corners; the average of the five, the maximum, and the minimum are reported. To determine the proportion of illumination reaching the test plane directly from the lamp, these measurements were repeated with the top and the sides of the lamp shade and the adjacent wall covered with opaque black cloth. In the case of the recessed ceiling units the reflected light was measured by shielding the meter from direct light. Because the test plane was parallel to the wall, and because the measurements were made without a subject in sewing position, the amount of reflected light reaching the test plane from the wall was higher than it would be in normal usage.

An approximate measurement of general room illumination was obtained by taking horizontal footcandle readings 30 inches above the floor at five points: in the center of the room, and halfway between the center and each corner. All footcandle measurements were made with a color-corrected multi-cell diffusing plate, designed to eliminate errors resulting from variations in spectral energy distribution and angle of incidence, and used in conjunction with a microammeter calibrated in footcandles. All lamps used in the tests were new lamps held at rated voltage.

Brightness measurements were taken with a Luckiesh-Taylor meter at a point on the center of the opposite wall 48 inches above the floor, and also on the floor immediately surrounding the test plane. The last column of Table I reports the authors' appraisals of each installation for quantity and quality of local illumination, and for freedom from sources of direct glare.

The results of the test measurements are summarized in Table I. It should be noted that all the data apply only to the standard test room, and to the conditions under which the tests were made.

Conclusions and Comments

From the measurements and observations made in this study, it is apparent that it is impossible to set up any one standard of optimum quantity and quality of light for all types of sewing. On the basis of both test results and observations, the authors are of the opinion that the current recommended footcandle levels for sewing published by the Committee on Residence Lighting in 1945[1] are not altogether adequate, or clearly defined. The following values and classifications are suggested for consideration:

Occasional sewing on light-colored fabrics	40 footcandles
Prolonged sewing on light-to-medium fabrics	80 footcandles
Sewing on dark fabrics, fine detail, etc.	150 or more footcandles

While these values are higher than those recommended by the Committee, all the indications are that the higher levels are more desirable, and present-day lighting equipment now makes it possible

to attain them practically and economically in the home.

As previously stated, for most sewing tasks totally indirect light is less advantageous than light with some direct component. With all the Certified lamps, 75 to 85 per cent of the light delivered on the test plane came directly from the source, producing a quality of illumination that seemed to be satisfactory for the materials tested.

The authors feel that diffusion and low source brightness are not so necessary for sewing as for reading. In fact, specular reflection from the needle is usually helpful, although with very high source brightnesses it is possible for it to become annoying. Standard inside frosted lamps in single or double socket table models, although they produce slightly harsher shadows than either Certified lamps or the 150-watt R-40 white indirect-lite lamp, still in general provide a reasonably good quality of light for sewing.

An inspection of the general room illumination and brightness values listed in Table I shows that with one or two possible exceptions the luminaires tested do not by themselves provide sufficient room lighting to maintain comfortable brightness ratios with any task of reasonably high reflectance. Furthermore, these measurements were made in an empty test room. In most furnished rooms the illumination readings would be even lower.

Figure 3. The Certified Senior floor lamp with a 100-200-300-watt incandescent lamp and a 32-watt circular fluorescent lamp provided the highest illumination level of any of the portables tested: an average of 100 footcandles on the specified test plane. See Test No. 9, Table I.

Illumination from Portable Lamps: As shown in Table I, the portable lamps tested produce a range of from 30 to 100 footcandles (average) on the sewing plane. These levels are about as high as can be attained with conventional types of portable lamps. When sewing, one consciously or unconsciously moves the work to the place where it will receive the most light, so that the maximum readings are perhaps more significant than the averages. It is also noteworthy that, because of the small fixed area of attention in sewing, uniformity over the test plane is of less consequence than it is in reading.

The table lamps tested, on a 25-inch table with an observer of average seated eye height on an 18-inch chair, gave complete freedom from direct glare in either the sewing or the relaxed position, because the lower edge of the shade was below eye-level. The same lamps placed on a higher table beside a lower chair might very easily become annoying if the under-shade brightness were in the field of view. To avoid this condition, all table lamps must be carefully chosen with respect to table and chair or davenport height, and individual seated eye height. If a table or floor lamp, designed to produce an acceptable quantity and quality of light for sewing, were so constructed that it could be raised or lowered by means of an adjustable shaft, the problem of under-shade brightness could be solved for various combinations of these dimensions.

Local Illumination from Reflector and Projector Lamps: When illumination levels beyond the 100-footcandle range are desired in the home, it usually becomes necessary to use some type of concentrating equipment. Reflector and projector lamps recessed in the ceiling or mounted locally are a practical and convenient means of supplying additional footcandles.

Reflector and projector spot and flood lamps (150 watts) recessed in the ceiling (as shown in Tests No. 13 and 14 in Table I) produce a high degree of uniformity of illumination on the test plane. However, the footcandle levels provided by the flood lamps — 21 average for the R-40, and 48 for the PAR-38 — are no greater than can readily be provided by portable lamps. On the other hand, the R-40 spot lamp, with an average of 117 footcandles, and the PAR-38 spot with an average of 200, produce an effective quantity of "plus lighting" which is definitely worthwhile.

One disadvantage of this type of installation is that the high footcandle levels are accompanied by high source brightness which results in conspicuous specular reflections from the needle, the thimble, fingernail polish, and shiny fabrics. However, all

Figure 4. A handy clamp-on device for attaching a 75-watt R-30 reflector lamp to the shaft of a floor lamp. A flood-type lamp used in this manner supplies at least 100 footcandles on the sewing plane, depending on distance and angle.

of these elements are continuously in motion, and the degree of annoyance is ordinarily not too severe. The sensitivity of the individual, and the length of time for which the installation is used, will determine whether or not the condition is uncomfortable.

One method of bringing reflector and projector lamps closer to the task is to install them in the conventional down-turned bridge lamp, or one of the more modern adjustable floor or table lamps, which provide a convenient socket and a shade to shield the lamp. The 75-watt R-30 flood lamp used in this manner supplies at least 100 footcandles on the sewing plane approximately 15 inches from the end of the lamp, and the 150-watt R-40 flood a minimum of 250 footcandles. Care should be taken to arrange the lamp so that the bright inner surface of the shade is not in the line of vision.

Another simple method of mounting a 75-watt R-30 lamp is to use a photographer's swivel socket-holder clamped to the shaft of a floor lamp. The use of some sort of shield around the lamp is recommended. If the lamp is used bare, it is essential that it be placed well below eye-level, and carefully aimed so as to avoid direct glare from the end of the bulb. The tilting of the source for comfortable illumination will vary with seated eye height, and the footcandles obtained will vary correspondingly. Because of the angle at which the light is directed, specular reflection is less likely to be annoying than it is when the lamps are mounted in the ceiling.

Obviously, with such values of local lighting, considerable general room illumination from other sources must be added if the brightness of the surroundings is to be brought up to acceptable degrees of contrast with light or medium-colored sewing tasks. For example, if a fabric with a 20 per cent reflectance is lighted by 100 footcandles, its brightness will be 20 footlamberts. If the floor has a reflectance of 20 per cent as in the standard test room, then 10 footcandles of general illumination will produce only a ten-to-one brightness ratio between the work and the floor. In view of the fact that the reflectance of many fabrics is higher than 20 per cent, and that of most floor coverings lower than 20 per cent, the attainment of even a ten-to-one brightness ratio in the average home often becomes difficult.

A complete study of lighting for home sewing would include at least four parts:

1. Light for hand sewing
2. Light for machine sewing
3. Light for the cutting or tracing table
4. Light for fitting purposes

Acknowledging that the present investigation has opened up a number of questions which deserve fuller technical analysis, the authors hope that it still has made some contribution to the first of these four. This study was undertaken because it is recognized that sewing is a difficult visual task, and requires careful lighting. That the subject also deserves consideration on the ground of the growing popularity of sewing in the home is shown by figures quoted in a recent issue of a fashion magazine:[6] In the last ten years department store sales of yard goods have tripled, and pattern sales have mushroomed to more than 100 million a year, because today more than 28 million American women are sewing at home. In the light of these facts, it is to be hoped that further examination will be made of part 1, above, and that studies of parts 2, 3, and 4 will follow, in order to supply additional basic information as to the amount and kind of light needed for sewing in the home.

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DISCUSSION

MATTHEW LUCKIESH*: I congratulate the authors on a very commendable effort to obtain quantitative data pertaining to the visibility of critical details involved in hand sewing. It is gratifying to note an increase in such efforts, for specifications of light and lighting as well as brightness and brightness-ratios must be based on a foundation of measurements of the factors involved in seeing and in seeing conditions.

The authors obtained satisfactory results for the condition of general or indirect lighting, but they encountered some difficulty in making satisfactory measurements, or rather in interpreting them, when a direct component of lighting was involved. This is neither their fault nor a shortcoming of the visibility meter. With a combination of general and direct lighting, the visibility of the critical details which are involved in sewing is affected not only by the brightness-level of the task but by the modeling due to highlights and shadows. Specular reflections are also involved and their effect on the visibility of the critical details is due to a complex combination of the direction of light, the brightness of the light-source, the position of the observer and the brightness-levels of the critical details and of their background. This complex combination is difficult to control and to describe. However, in any given case, measurements of visibility provide the most, if not the only available, practical approach. Visibility measurements can actually determine the influence of any of the various factors if sufficient control of the factors is obtained. However, such a detailed investigation requires a great deal of time and effort.

The foregoing is in no way a criticism of the excellent paper. In fact, it is a compliment to the authors for their recognition of the need for measurements to replace guess-work and for their courage and determination to attack a very complex problem in a sound manner. Indeed it is a pleasure to congratulate the authors on a worth-while attack which has resulted in a worth-while contribution. I hope they will continue their work along this line.

MARY E. DOOLS**: The introduction to this paper states three points of importance often overlooked, or unacknowledged. The clear recognition of the points is in itself an advantage to the home-sewer since recognition of a problem leads to a solution.

Miss Fahsbender and Miss Presbrey say "this study was undertaken with the purpose, first, of investigating the lighting conditions most satisfactory for hand sewing in the home." Their paper shows the diversity of factors in hand-sewing is so great that only a beginning of such a study could be made. It may be hoped that the study will be carried further.

A second objective of the study as stated by the authors, is, "determining to what extent these conditions can be provided by common types of available home lighting equipment."

The answer to this objective is tabulated in Table No. 1 — Performance of Test Luminaires. Careful check of the Table, particularly in that column titled Comments, shows that no one of the 14 luminaires checked gave complete satisfaction at all parts of the test.

These comments are made not as criticism of the paper but rather to emphasize the problems inherent in home-sewing which must be considered by an illuminating engineer who plans lighting for such a task.

Discussion of a study of this paper might include as its outstanding point this statement of the authors "we are of the opinion that the current recommended footcandle levels for sewing published by the Committee on Residence Lighting in 1945 are not altogether adequate or clearly defined."

The authors continue and say "the following values and classifications are suggested for consideration." They then suggest reclassification of the sewing tasks and increase of recommended footcandles. To one who remembers the discussion, and even hesitation, with which the first table of illumination values for Recommended Practice was made, the authors of this paper certainly join leaders in a parade of progress.

RUTH MORRIS*: We who are doing lighting work in customers' homes commend Miss Fahsbender and Miss Presbrey for their work in preparing the paper entitled "Lighting and Seeing Conditions for Hand Sewing in the Home." It has long been recognized that hand sewing on dark material with dark thread is one of the most critical eye tasks performed in the home. This, plus the fact that a great part of hand sewing is done by people who have reached the age where the use of eyeglasses is necessary for any close work, makes the matter of lighting for sewing doubly important.

The footcandles from equipment in a test room obviously exceed those obtainable on the working plane from similar equipment used in the average home. There is enough difference in these illumination values to indicate the need for still greater efficiency in portable lamp design to help us achieve suitable lighting results.

I heartily concur in the authors' suggestion that the I.E.S. revise upward its recommended footcandle levels for sewing. My own experience warrants the opinion that their recommendations for the various classifications are quite conservative.

There's a real job to be done to provide the quantity and quality of illumination needed within the home for sewing as well as for other visual tasks. I.E.S. studies such as this one and others, covering lighting for a particular task, render our job in the field easier. They give to our efforts the support of what the LaSalle Sales Training Course terms "expert opinion." Therefore, we sincerely hope that further studies dealing with other phases of home sewing will be undertaken, as recommended by the authors of this paper.

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*Georgia Power Co., Atlanta, Ga.

New Semi-Automatic Distribution Photometer and Simplified Calculation of Light Flux

By GEORGE R. BAUMGARTNER

IN THE relatively few years since the introduction of the fluorescent lamp more changes in photometric technique have taken place than in the period of over half a century between fluorescent and the inception of the filament lamp. Among the many improvements the following three are perhaps the most outstanding and deviate the most from former practice.

Visual photometry which had been used almost exclusively for measuring light distribution from filament lamps and lighting equipment was replaced by light sensitive cells and indicating instruments. Not only was this true in the laboratory but also for portable light measuring devices.[1]

There was a shift from direct current energy and storage battery banks to alternating current furnished through voltage stabilizers, regulating and filtering apparatus.

The third and most recent innovation is the use of automatic recording equipment for plotting light distribution curves which have effected savings in time and labor and have made feasible simplified calculations. A new equipment and a new simplified method of calculation are the principal subjects of this paper.

Methods usually employed at the present time to determine light distribution characteristics of fluorescent lighting equipment require a number of readings depending upon the classification of light distribution from the luminaire. Many of these have been adequately described previously.[2] About 30 readings are taken on totally direct and totally indirect distributions and some 60 measurements are taken on semi-direct, general diffusing and semi-indirect classifications. These calculations require considerable time in addition to the actual laboratory work. Automatic recording and simplified calculations contribute to reduce substantially these time absorbing operations.

Automatic Recording Photometer

The Recording Instrument. — In order to reduce the laboratory work and the calculation time, the indicating microammeter was replaced with a recording type instrument,[3] such as shown in Fig. 1. This instrument has a 10-inch horizontal deflection and there are one hundred divisions across the scale. The chart travels vertically downward at a speed of 18 inches per minute which may be varied depending upon the gear ratios selected.

The instrument has high sensitivity and its response to changes in illumination is practically instantaneous. With a single light sensitive cell equipped with color-correcting filter a full scale deflection representing 1000 candlepower may be obtained at a test distance of approximately 20 feet. The color-correcting filter used has an absorption of approximately 90 per cent; if the filter is omitted a full scale deflection would, therefore, represent 100 candlepower. Further sensitivity increase may be obtained by adjustment of the potentiometer used across the amplifier input.

The Luminaire Supporting Mechanism

The luminaire supporting mechanism (Fig. 2) consists essentially of two parallel channels six feet apart mounted on the ceiling beams of the laboratory twenty-four feet above the floor. Riding in each channel are two individual sets of wheels furnishing a four-point suspension for the eight-foot

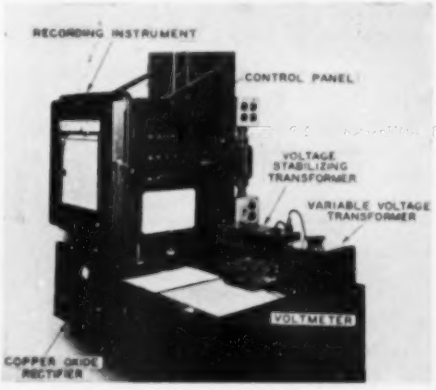


Figure 1. Recording and control instruments.

A paper presented at the National Technical Conference of the Illuminating Engineering Society held September 20-23, 1949, French Lick, Indiana. Author: General Electric Company, Nela Park, Cleveland, Ohio.

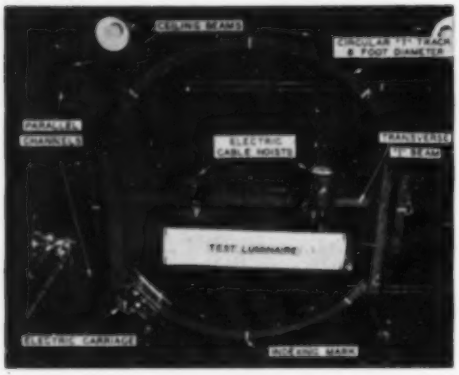


Figure 2. Luminaire supporting mechanism.

circular "T" track. The circular track, therefore, may be moved bodily along the channels.

Riding on this circular "T" track are four more sets of wheels which provide a support for a transverse "I" beam. Thus the "I" beam and hoist assembly may be rotated and moved laterally to position the luminaire under test. The "I" beam carries two 250-pound electric cable hoists. These are also mounted on wheels which provide variable spacing between hoists to accommodate fixtures of different lengths.

With this type of mounting, the lighting unit may be moved horizontally or rotated through 180° on the tracks and positioned vertically by means of the cable hoists. The entire mounting is positioned on the parallel channels by hand and remains fixed for the duration of the test.

The "I" beam and hoist assembly is rotated on the circular track by means of an electric motor and reduction unit carriage which is controlled from below. The circular track is indexed at 45° intervals and a reference line is located on the "I" beam support for setting angles (broadside, end-wise or any intermediate angle). The electric hoist motors can be operated from below either together or individually for positioning and leveling the test unit. The movements of the luminaire during a test may be clarified by the general views in Figs. 9 and 10.

The Light Sensitive Cell Rotating Arm and Driving Assembly

The rotating arm supports the light cell at a distance of 20 feet from the luminaire center. The arm is built up of two pieces which are framed together with a saw tooth bridging to increase strength and stiffness. In this construction the counter balance arm is limited to 24 inches. The counter weight is made up of the motor driving assembly and two pieces of steel plate all mounted on the short end of the arm. Substantially perfect balance resulted with a total of 180 pounds. (Fig. 3).

At the far end of the cell arm another arm is attached to position the cell five feet out from the supporting arm.

A 1/25 hp. synchronous motor is used to swing the cell arm. The drive includes a variable speed reduction unit[4] and magnetic fluid clutch.[5] The magnetic fluid clutch is used between the reduction unit and the gear drive as a safety feature to prevent damage to the parts and also to provide slippage so that the cell can be rotated by hand quickly, if desired.

Both the cell arm and recording chart are driven by synchronous motors to keep in perfect step regardless of line frequency variations. The cell arm moves 180° in one minute and as previously mentioned the chart speed is 18 inches per minute. Therefore, one inch on the chart represents a 10° angular movement of the cell. The transverse rulings on the chart are ½ inch apart and are equivalent to 5 degrees of angular travel. A verti-

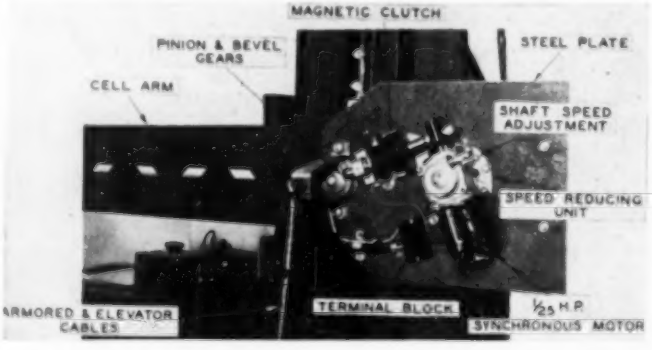


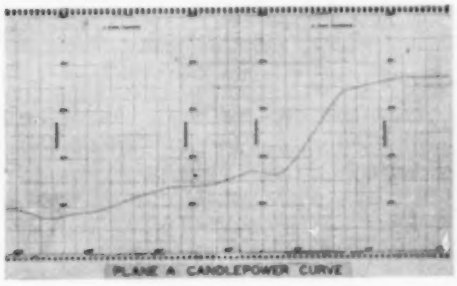
Figure 3. Rotating arm counter weight and driving assembly.

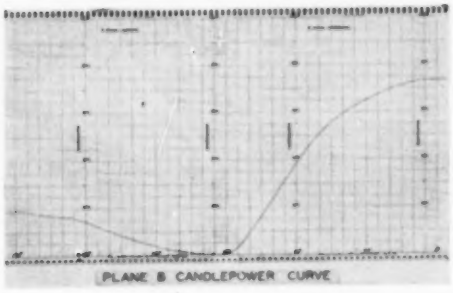
cal distribution from 0° to 90° or 90° to 180° requires one-half minute and a chart travel of 9 inches. Since both chart and arm speeds are adjustable more open or compressed plots may be used.

Vertical Track for Cell Arm

Having a ceiling height only slightly in excess of the required test distance (20 feet), distributions from 0-90° are taken with the luminaire up, near the ceiling and the cell swinging below the unit. Distributions from 90° to 180° are made with the luminaire lowered nearly to the floor and the arm swinging above it.

The entire rotating arm assembly can be moved vertically on a guide composed of two 6-inch channels. A wire cable attached to the face plate runs over a 6-inch pulley at the extreme top, returning down the back side of the beam to the counter weight for the entire arm assembly. Both the arm assembly and the counter weight are fitted with wheels which ride on the edges of the channels. The top pulley is driven by a 1/10 hp. motor and reduction unit and will raise or lower the rotating arm 20 feet in approximately one minute.





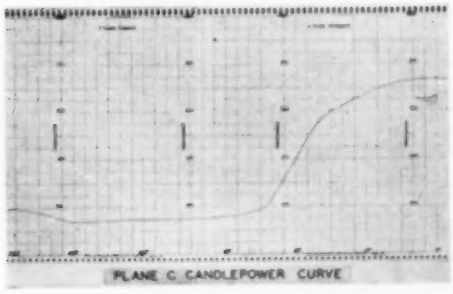


Figure 4. Candlepower recorded curves.

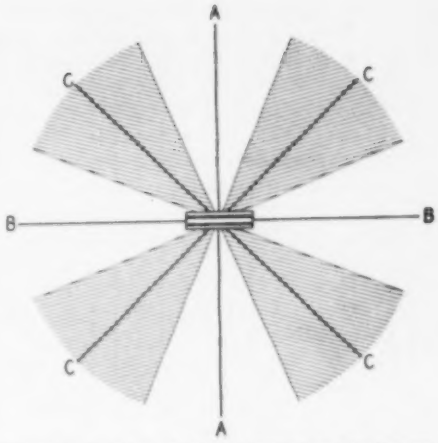


Figure 5. Relation of plane segments to 360 degrees.

Recorded Candlepower Curves

Fig. 4 shows the recorded candlepower curves for vertical planes *A*, *B*, and *C*. The bottom scale of the chart in this position is the left margin when the curve is being recorded.

Lumen Computations

Fig. 5 gives a picture of the relationship of the vertical planes, *A*, *B*, and *C*, to the test luminaire and the proportion each segment bears to the complete 360° around the luminaire.

As may be noted, plane *A* represents two segments 45° wide totaling 90° and equal to one-fourth the entire 360°. Plane *B* also represents a similar relation (one-fourth) to the total 360°. Plane *C*, however, represents four segments 45° wide adding up to 180° or one-half the total around the luminaire.

It can be readily seen that segments represented by planes *A* and *B* should each be given one-half as much weight as plane *C*. Thus when lumens are computed, candlepower values for planes *A* and *B* should each be multiplied by one-fourth the vertical zone lumen constant and candlepower values for plane *C* should be multiplied by one-half the vertical zone lumen constant.

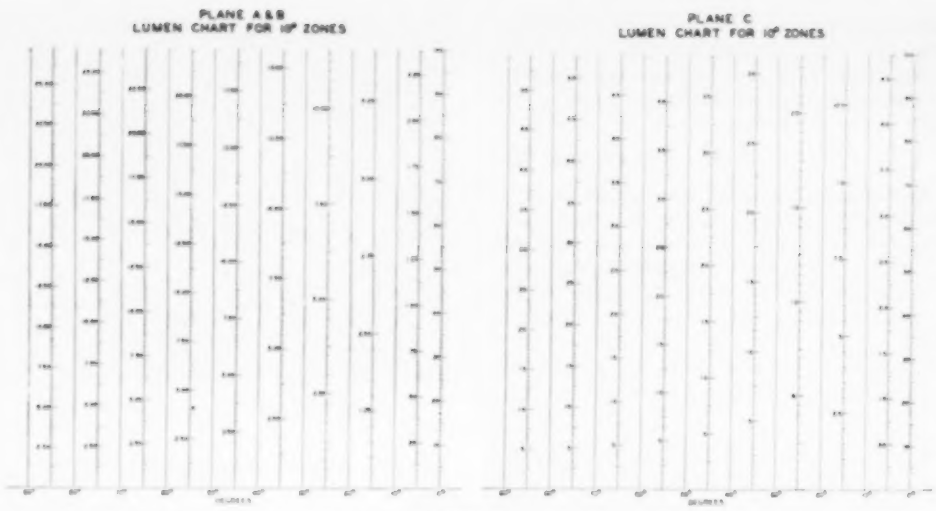


Figure 6.

There are several methods for computing lumens. The candlepower values may be multiplied by the fractional lumen constant or they may be weighted, averaged, and then multiplied by the usual zonal lumen constant. Another approach eliminating the use of slide rule or calculating machine can be used in the form of a weighted lumen chart for each plane as shown in Fig. 6. The lumen chart consists of a group of scales at 10° intervals beginning at 5° and continuing 15°-25°, etc. to 85°. These individual scales are derived by multiplying a 100-candlepower scale by either one-quarter or one-half the lumen constant for each 10° zone beginning with the 0-10° zone.

This saves considerable time by permitting the lumen values to be obtained directly from the recorded candlepower curve when the transparent lumen chart is superimposed on the recorder chart. (Fig 7). At each zonal mid-point (5°-15°-25°, etc.) where the candlepower curve crosses the lumen scale, the lumens may be read for each zone. For a 1000-candlepower scale, lumen charts should be multiplied by ten. For example, from Fig. 7 the lumens in plane A for 0-10° are 17.5; for 10°-20°, 52; 20°-30°, 83; etc. The lumen chart used has scales which are one-fourth the usual zonal constants.

Recorder Scale Calibration

The adjustment of the recorder scale in candlepower is by a substitution method. The lamps to be used in the test luminaire are mounted on a check-

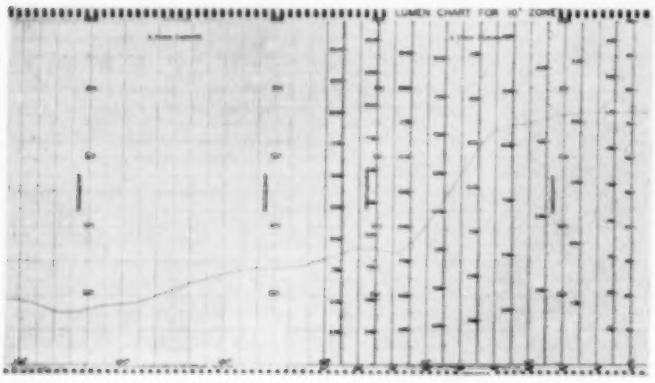


Figure 7. Lumen chart superimposed on recorded candlepower plot.

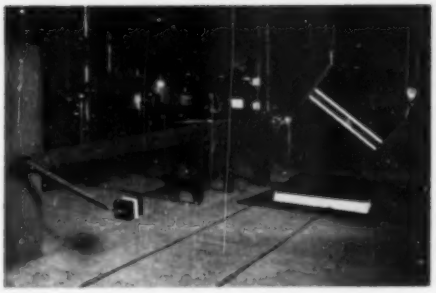


Figure 8. Light cell checkup.

up rack supported by the electric hoists and placed in the low position. The lamps are tilted by raising one end, thus reducing mutual heating during checkup. (Fig. 8). The checkup rack has a black separating fin between the lamps to eliminate interreflection between lamps.[6]

The lamps are operated on the ballast equipment in the luminaire. The ballast is supplied through a stabilizing transformer and rated voltage is set by a variable voltage transformer. The cell arm axis is lowered to a point opposite the center line of the checkup lamps and the cell arm extended horizontally which aligns the cell perpendicular to the lamps and in a plane intersecting the mid-point between the lamps. By means of the potentiometer on the recorder the stylus is set at 454 candlepower. It has previously been determined that dividing the lumen output of a fluorescent lamp by a standard factor of 9.25 gives the candlepower perpendicular to the lamp. The candlepower from a single 40-watt lamp when delivering 2100 lumens is 227. Two lamps, therefore, produce 454 candlepower.

After the checkup the lamps are replaced in the unit which is then hung on the hoist hooks. The luminaire is raised to the uppermost position 22 feet above the floor; the cell arm is raised on the vertical guide until its axis is opposite the center point between the lamps in the luminaire. The arm is swung downward to place the cell at the zero degree position directly below the luminaire. (Fig. 9). Everything being in readiness, the cell arm and chart motors are started simultaneously and the candlepower curve is traced on the chart for vertical plane *A* from 0° to 90°.

At the end of the run just completed the cell arm is horizontal. The cell arm and unit are lowered to 2 feet from floor. (Fig. 10). The cell arm and chart motors are again started and the candlepower curve completed for plane *A* from 90° to 180°.

The luminaire is positioned on the circular track for planes *B* and *C* and the above procedure repeated.

After recording candlepower distribution for the three vertical planes the lumens are determined as

Figure 9. Photometer and cell in position to start recording of plane *A*.

Figure 10. Photometer and cell in position to continue recording of plane *A*.

previously described. The lumen values are totaled and the sum divided by the rated output for two 40-watt lamps. This gives the over-all efficiency of the luminaire.

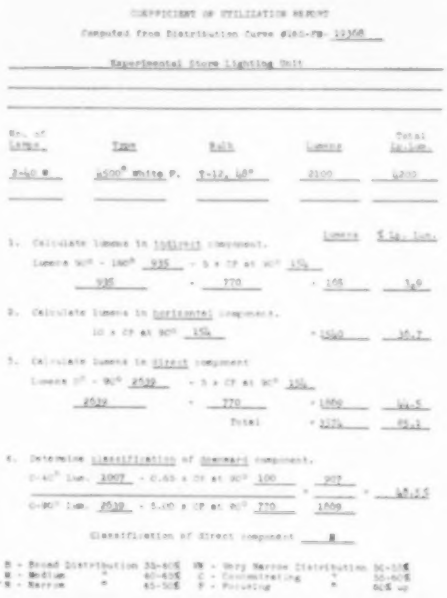
The cell housing pick-up covers an area of about 10 feet square. To minimize floor reflection errors a flat black background should be provided when the test unit is in the lower position.

Because of the long dimensions of present day light sources test distances of 20 feet or more are required. When horizontal test setups are used the test luminaire must be mounted in other than its normal operating position. This has resulted in abnormal lamp operating temperature and bothersome mechanical problems of support. These problems have been eliminated with the type of mounting used in this photometer as the unit is tested in its normal position of operation.

Calculation of Utilization Coefficients

The calculation of coefficients is generally considered an involved and time-consuming operation. The following method may not greatly reduce the time required to accomplish these results but it is believed that the operation has been reduced to a routine which can be readily followed by a higher percentage of individuals in the lighting industry. When the detailed lumen output data have been derived, the first step is to make up a work sheet. (Fig. 11). From these calculations are obtained the upward, horizontal, and downward lumen percentages which are the basis for the coefficient calculations.

In order to determine the utilization efficiency, the indirect, horizontal, and direct components for a given lighting unit are multiplied by the fundamental factors which were developed by Harrison and Anderson[2] for various room sizes and finishes. After the values are obtained for one room size and


COEFFICIENT OF UTILIZATION REPORT

Computed from Distribution Curve #100-PB- 12368

Experimental Store Lighting Unit

No. of Lamps	Type	Bath	Lumens	Total Lumens
2-40 W	#500 White P.	9-12, 68°	2100	4200

1. Calculate lumens in indirect component. Lumens %

Lumens 90° - 180° 935 - 5 x CP at 90° 15%

935 · 770 · 105 5.0

2. Calculate lumens in horizontal component.

10 x CP at 90° 15% · 1050 25.7

3. Calculate lumens in direct component

Lumens 0° - 90° 2520 - 5 x CP at 90° 15%

2520 · 770 · 1890 44.5

Total · 3045 69.2

4. Determine classification of downward component.

0-40° Lum. 1007 - 0.65 x CP at 90° 100 · 907 · 48.0

0-90° Lum. 2520 - 5.00 x CP at 90° 770 1890

Classification of Direct component B

B - Broad Distribution 55-60% VN - Very Narrow Distribution 50-55%
M - Medium " 60-65% C - Concentrating " 55-60%
N - Narrow " 65-70% F - Focusing " 60% up

Figure 11. Preliminary work sheet for coefficients of utilization.

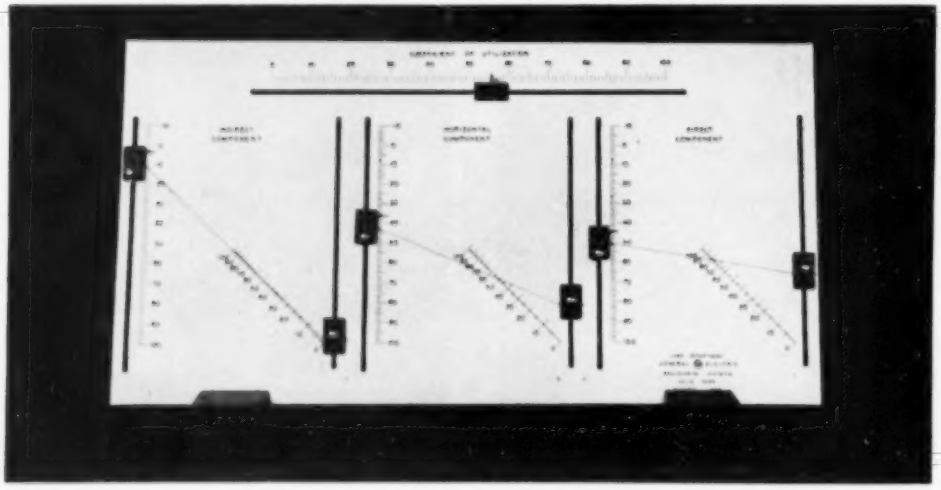


Figure 12. Front view of coefficient calculator.

TABLE I.—Tabulation of Values for Room Index A, 75% Ceiling, 50% Side Wall

	Ind.	Hor.	Direct	
Percentages from Work Sheet....	3.9	36.7	44.5	
Factors from Tables, Amick[7].....	.56	.65	.93	
	.02	.24	.42	
Coefficient of Utilization				.68

finish, the three components in percentage of lamp output are added together to give the final utilization coefficient for this room.

Three nomographs for indirect, horizontal, and direct components are etched in an aluminum plate equipped with sliders and scales, Fig. 12. The lumen output percentages derived from work sheet Fig. 11 are to be set on the respective vertical scales.

One feature of this calculator is that once the vertical sliders are set they remain fixed for the entire series. The right-hand sliders are adjusted so that the appropriate basic factors for room sizes and finishes are indicated on the three slanted scales. The three nomographs each perform a simple multiplication and by an inter-connecting thread the three resulting products are automatically added which indicates the coefficient of utilization by the pointer on the top horizontal scale.

An example of the operation of this machine is shown in Table I.

The photometry of fluorescent lighting equipment requires considerably greater vigilance because of auxiliary operating equipment for lamps, color of source, temperature effects on light output, and source size. All of these as well as larger mechanical equipment required for mounting heavier and bulkier luminaires contribute to greater time expenditures. In view of this, therefore, the reduction in over-all laboratory and computation time in many cases justifies the initial investment by the savings effected in the test work routine.

The author wishes to give credit to Mr. G. S. Merrill for the basic principles used in the nomographs and thanks to Messrs. V. W. Jones, E. P. Meko and W. R. Stephens for their assistance in the construction of the new recording photometer.

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DISCUSSION

W. F. LITTLE*: Early last year the Bureau of Standards purchased and installed a recorder which could be actuated by either barrier layer photocells or thermopyles. It is interesting to note that immediately and independently, three companies followed suit, each without the knowledge of the other two. John Bock at Schenectady, George Baumgartner at Cleveland, and we at ETL. Each employs a different recorder; all three accomplish substantially the same result.

Mr. Baumgartner's ingenious method of picking off lumen values is extremely interesting and valuable. We, however, must plot the individual curve and give the candlepower and lumen data for the average curve. For this reason we have proceeded on a rather different tack.

ETL is fortunate in having Thyrotron controlled voltage which holds the line within ¼ per cent and in general to within 1/10 per cent.

The original equipment developed for tests of fluorescent units at ETL was designed around the 4-ft lamp, using a 20-ft distance or at least five times the maximum dimension. Before the equipment was completely developed the 5-ft lamp came into being. Changes were made to accommodate this length and the distance increased to 25 feet. No sooner had this been accomplished than the 8-ft lamp was thrust upon us. We hope that no longer lamps will be forthcoming, as our backs are now against the walls, using a 40-ft distance.

The scheme for mounting the bare lamps as well as the unit is somewhat similar to that described by G. A. Horton,** that is, it consists of three forks, the inner one turning the unit of lamps in any position around the axis of the unit. The middle fork orienting the unit with respect to a line normal to the axis and passing through nadir and zenith.

The third or outer fork is capable of revolving around the vertical axis passing through the center of the unit. When the candlepower distributions are made whether parallel, normal or 45° to the tubes, the unit is always rotated around a vertical axis.

The rotation of the unit is controlled by a synchronous motor revolving the outer fork at the rate of one revolution in six minutes.

At ETL the standard is set with the bare lamps viewed by the cell through the mirror. The mirror is hinged so that it can be folded down out of the way when not in use. It also forms a convenient screen for the floor. Rods

*Electrical Testing Laboratories, Inc., New York, N. Y.

**"Modern Photometry of Fluorescent Luminaires," to be published in ILLUMINATING ENGINEERING.

with lamp terminals are placed in the fixtures so that the bare lamps can be operated on the fixture ballast.

The bare tubes, as far as possible, are placed the same distance apart for each standardization and correction for the added light due to interreflection is applied.

The series of curves (Figure 1 of the paper) is the result of an investigation to determine the increased candlepower due to interreflection for different number, size and spacing of lamps.

After standardization of the bare tubes, the fork is reversed and the tubes are removed and placed in the unit, which is mounted on the opposite side of the fork. This can be done in a moment with worm gear sprocket and chain. The fork carrying the unit is turned through 180° so that the unit is now viewed through the mirror by the cell.

The fork carrying the unit is turned 45° with the luminaire facing the cell, and the mirror turned downward. The unit is oriented to any desired angle with respect to the vertical. It is held in place with a worm gear. Any sag can be completely removed by the worm, chain and sprocket. The mirror is raised to the point where the reflection from the floor is entirely eliminated.

The protractor attached to the outer fork is projected with a magnification of 8 diameters.

A selsyn transmitter system involving a transmitter rotor attached to the outer fork and a synchronous receiver rotor mounted above the recording device, which is located on another floor, is used to indicate the angles at which measurements are being made. These angles are also indicated through electrical contacts.

The synchronous motors that respectively rotate the outer forks and the recorder chart are arranged so that the plots for distributions about the opposite sides of the luminaires are superimposed—a device permitting rapid checking of averages.

In order to utilize as much of the 12-inch chart as practicable, the unit is started at 0° (nadir) with the pen at indication 135°. The unit is placed at an angle of 5° to the right, the synchronous motor started and at the instant it reaches 0° the recorder is started and a continuous curve is plotted up to 140°. A clutch on the motor is released, the fork brought back to 5° on the left, the synchronous motor reversed, the chart on the recorder brought back to 0°, and the previous procedure followed for the three additional planes measured. In this way, the unit is measured in the four quadrants and the plot for opposite sides are superimposed. For the light above the horizontal the inner fork carrying the unit is rotated 180° and the light in the upper hemisphere investigated.

The agreement between the point by point potentiometer indicator method and the recorder is excellent.

F. H. Wyeth*: Mr. Baumgartner is to be congratulated on presenting a very interesting paper which should be of considerable assistance to any laboratory interested in building equipment for drawing a large number of distribution curves automatically.

It is well known that the light versus current relationship is approximately linear for barrier layer cells when

*Leeds & Northrup Company.

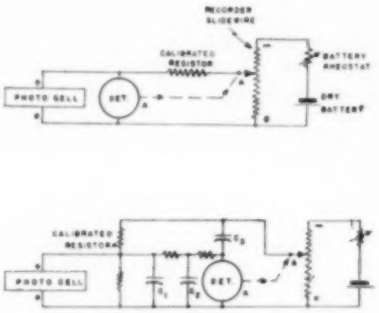

Figure I. Circuits for microampere (null current) recorder. A. (Above) Basic circuit. B. (Below) Circuit with filtering and damping components added.

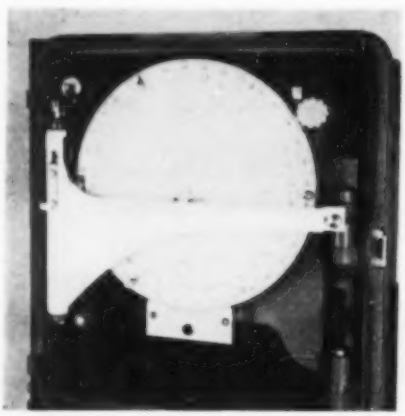

Figure IIA.

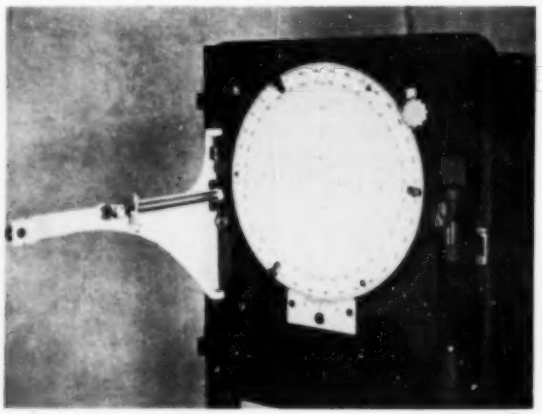

Figure IIB.

the cell is used in a circuit of "zero resistance."[1, 2, 3] As it is the short circuit (zero voltage) current that is the linear function of the radiation, a current recorder has been developed of the slidewire null type which presents zero voltage across the barrier layer cell at balance.

The drawing in Fig. 1A shows the basic circuit and Fig. 1B the same circuit with filtering and damping components added to adapt it to the electronic type automatic recorder.

The null current recorder employs a sensitive feed back amplifier and permits current ranges of 0 to 0.25, 0 to 0.5, and 0 to 1.0 microampere full scale.

For the curves shown by Mr. Baumgartner, the 10° angles are equally spaced on the time axis of the strip chart. The chart speed of 18 inches per minute permits precise reading of angular position. For many photometric engineers, a polar diagram of angle versus lumens is easier to visualize and use.

Fig. IIA and IIB show a type of round chart recorder which has a circular chart driven by a selsyn. The pen operates over a zero to 5" radius. The same type of "zero resistance" null current circuit as is used in the strip chart recorder described by Mr. Baumgartner can be used in this round chart recorder.

For research work both the strip chart and the polar chart are useful. For routine measurements by lamp and fixture manufacturers, the polar recorder may prove more desirable.

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(2) "Photometry with Barrier Layer Cells" Louis E. Barbrow—Journal of Bureau of Std. Vol. 25, 1940.

(3) "Electronically Balanced Recorder for Flight Testing and Spectroscopy," A. J. Williams, W. R. Clark and R. E. Tarpley, A.I.E.E. Transactions, Vol. 65, 1946.

G. R. Baumgartner: One point which requires further emphasis is the error encountered in testing fluorescent luminaires when the test distance used is not five times the length of the source. In the past it has been generally accepted that the per cent variance from the inverse square law applied to fluorescent photometry. This is not essentially true. The deviation curve indicates an error of about 2.5 per cent when footcandle measurements are made normal to an eight-foot source at a distance of 20 feet or 2½ times the length instead of 40 feet or 5 times the source length.

It should be remembered when running a candlepower distribution curve that a substitution method is employed. For example, the eight-foot lamps used in the test luminaire are also used in the calibration of the light cell and recording instrument at the same test distance. The error resulting from measuring at closer than 5 times source length, namely 20 feet, is present in the calibration which partially compensates. Furthermore, the 2.5 per cent error is obtained when the illumination is measured perpendicular to the source. This occurs only when the candlepower measurements are made in the A plane perpendicular to the unit. In the B and C planes and at the higher angles in these planes the source is foreshortened.

The author wishes to point out that the deviation from the inverse square law does not necessarily apply to distribution photometry of eight-foot sources when a test distance of 20 feet is used. The difference is materially less than 2.5 per cent for the reasons given, namely, (a) the calibration by substitution method and (b) the foreshortening in B and C planes which represent greater lumen zone areas.

Cold Cathode Lights a Detroit Classroom

In the relighting program for some 620 Detroit classrooms, cold cathode installations are contemplated, of the type shown here. Six fixtures mounted on the existing outlets have been used in this standard classroom of 22′ x 30′, with a 12′ ceiling. Each fixture uses four 120-ma cold cathode lamps rated at 2400 lumens per lamp. Total wattage of the installation, including ballast loss, is 1272 watts.

An average of 30 footcandles of uniform illumination is produced throughout the room. The relatively low brightness of the lamps and the use of light ceilings produced low brightness contrast between the fixture and the surroundings, and have resulted in well-diffused overall lighting.

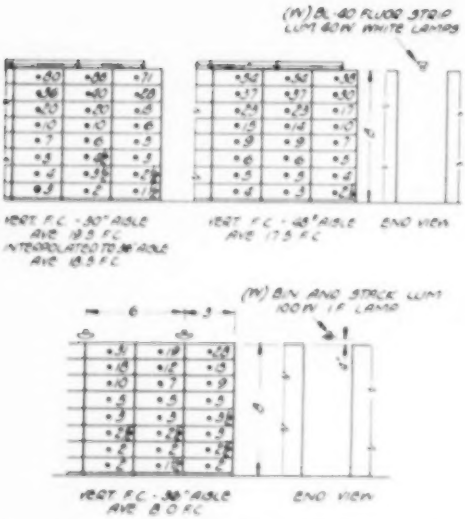
Installation by Illuminating Engineering Company, Hazel Park, Michigan.

Fluorescent Vs. Filament For Lighting Stock Bins

A COMPARATIVE study of fluorescent and filament lamp stack lighting luminaires has been carried out at the Westinghouse Electric Supply Company, Cleveland, Ohio. Some of the 30-foot aisles of the stock room used in the experiment were illuminated by a continuous row of seven luminaires, each containing one 40-watt fluorescent lamp (see photograph above). Since the fluorescent lamp is lower in brightness when viewed lengthwise, shielding was considered unnecessary for this application. Other bins were lighted by 100-watt filament lamps in stack lighting luminaires (five per row). Aisle widths varied somewhat.

Illumination levels after approximately six months operation are shown in the drawing at left. All readings were measured in a vertical plane with an incident-light-corrected, multi-cell light meter. These data show that the continuous light source provides the more uniform longitudinal distribution. The large variation in illumination from top to bottom with both methods is due to the wide range in distance from luminaire to the lighted surface.

A cost analysis showed that the overall cost per footcandle was twice as much with filament lamps as with the fluorescent. However, the filament lamps are more practical in cases where the stock aisles are entered infrequently and the lights are turned on for short periods of time.


(W) BK. 40 FLUOR. STD. CLR. 60 W. WHITE LAMPS
VERT. F.C. - 30" AISLE
AVE. 19.5 F.C.
INTERPOLATED TO 36" AISLE
AVE. 18.5 F.C.
VERT. F.C. - 48" AISLE
AVE. 17.5 F.C.
END VIEW
(W) BIN AND STOCK LUM.
100 W. I.F. LAMP
VERT. F.C. - 30" AISLE
AVE. 8.0 F.C.
END VIEW

Comparison of illumination levels of stock bin installations with fluorescent and filament lamps, after approximately six months operation.

Adapted from "Lighting a Stock-Bin," by W. H. Kahler.

Lamps for Aircraft, Aerodrome and Airway Lighting

I.E.S.—S.A.E. Recommended Practice of Lamps for Aviation

Prepared by Joint IES-SAE Subcommittee on Aviation Lamps

Foreword

In the interest of guiding design practice toward the use of lamps best suited for each of the various aviation lighting applications, a joint subcommittee of the IES Aviation Lighting Committee and the SAE Lighting Committee has prepared two "Recommended Practice" lamp tables. One of these covers lamps for aircraft lighting, and the other covers lamps for aerodrome and airway lighting.

These tables list the lamps by application. They identify the trade numbers of the lamps, the Army-Navy part number, if any, and include essential design data of interest to equipment designers.

It should be emphasized that these tables do not include all of the lamps now available or now used in the various aviation lighting applications. In omitting some of the lamps now employed, the committee had no intention

Approved by the Council of the Illuminating Engineering Society January, 1949; Approved by the Society of Automotive Engineers January, 1950.

LAMPS FOR AERODROME AND AIRWAY LIGHTING IES-SAE RECOMMENDED PRACTICE
The lamps shown are those *recommended* for the service indicated. This list is not intended to be a catalog and hence does not include many types of lamps now in use.

Line No.	Service	Volts or Amps	Watts or Lumens	Bulb	Base	Filament	Light Center Length (Inches)	Maximum Over-all Length (Inches)	Approx. Lumens	Rated Average Laboratory Life (Hours)[1]	Line No.
1.	Runway, Threshold, High Intensity	6.6A	200W	T-14	Med. Pref.	C-13	2 1/4	5 3/4	4800	75	1.
2.	Runway, Threshold, High Intensity	115V[2]	500W	T-20	Med. Pref.	C-13D	2 1/4	5 3/4	13000	25	2.
3.	Approach, High Intensity	12 1/2 V	250W	PAR-56	2 Contact Lugs	C-6		5 3/4		100	3.
4.	Approach, High Intensity	115V	400W	PAR-56	2 Contact Lugs	CC-13		5 3/4		100	4.
5.	Approach, High Intensity	115V[2]	5000W	T-64	Mog. Bipost	C-13	6 1/8	13 3/8	164000	75	5.
6.	Elevated Strip, Runway, Threshold, Taxiway	6.6A	30W	T-10	Med. Pref.	C-2V	1 3/4	3 1/2	450	1000	6.
7.	Elevated Strip, Runway, Threshold, Taxiway	115V[2]	40W	T-10	Med. Pref.	CC-2V	1 3/4	3 1/2	425	1000	7.
8.	Elevated Strip, Runway, Threshold, Taxiway	6.6A	45W	T-10	Med. Pref.	C-2V	1 3/4	3 1/2	740	1000	8.
9.	Elevated Strip, Runway, Threshold, Taxiway	115V[2]	100W	T-10	Med. Pref.	CC-2V	1 3/4	3 1/2	1225	1000	9.
10.	Boundary[4], Wind Tee	115V[2]	25W	A-19	Med. Sc.	C-9	2 1/8	3 1/2	260	1000	10.
11.	Obstruction[4]	115V[2]	50W	A-19	Med. Sc.	C-9	2 1/8	3 1/2	550	1000	11.
12.	Obstruction[4]	115V[2]	67W	A-21	Med. Sc.	C-9	3 1/2	4 1/2	685	3000	12.
13.	Obstruction[5]	115V[2]	111W	A-21	Med. Sc.	C-9	3 1/2	4 1/2	1300	3000	13.
14.	Runway (Low Intensity), Boundary, Taxiway	115V[2]	40W	A-21	Med. Pref.	CC-2V	2 3/4	5 1/4	370	2000	14.
15.	Runway (Low Intensity), Boundary, Taxiway	6.6A	325L	A-21	Med. Pref.	C-8	2 3/4	5 1/4	320	2000	15.
16.	Range, Runway, Threshold (Low Intensity)	115V[2]	100W	A-21	Med. Pref.	CC-2V	2 3/4	5 1/4	1170	2000	16.
17.	Range, Runway, Threshold (Low Intensity)	6.6A	1020L	A-21	Med. Pref.	C-8	2 3/4	5 1/4	1000	2000	17.
18.	Beacon (Aerodrome, Airway, Hazard, Landmark)	30V	500W	T-20	Med. Bipost	C-13B	3	7 1/8	10000	500	18.
19.	Beacon (Aerodrome, Airway, Hazard, Landmark)	30V	1000W	T-20	Mog. Bipost	C-13	4	9 1/8	25500	500	19.
20.	Beacon (Aerodrome, Airway, Hazard, Landmark)	115V[2]	1000W	T-20	Mog. Bipost	C-13	4	9 1/8	20500	500	20.
21.	Beacon (Aerodrome, Airway, Course Light, Hazard, Landmark)	115V[2]	500W	T-20	Med. Bipost	C-13B	3	7 1/8	9250	500	21.
22.	Beacon (Aerodrome)[4]	6V	100W	PAR-56	Sc. Term.	C-6		4 1/8		500	22.
23.	Beacon (Obstruction Marker)	115V[2]	230W	PS-30	Mog. Pref.	C-9	5 1/2	8 3/4	3600	3000	23.
24.	Beacon (Identification, Obstruction Marker)	115V[2]	620W	PS-40	Mog. Pref.	C-7A	5 1/2	10 1/2	10800	3000	24.
25.	Floodlight (Landing Area or Runway)	32V	1500W	T-24	Mog. Bipost	C-13B	4	10 1/8	42000	100	25.
26.	Floodlight (Landing Area or Runway)	32V	3000W	T-32	Mog. Bipost	C-13B	5 3/8	14	88500	100	26.
27.	Ceiling Projector	12V	420W	G-25	Mog. Pref.	C-2V	3 1/2	5 1/4	10500	100	27.
28.	Ceiling Projector	[6]	900W	T-2	Sleeve			3 1/4 [7]	65000		28.
29.	Landing Direction Indicator (Tetrahedron)	115V[2]	10W	S-14	Med. Sc.	C-9	2 1/8	3 1/8	79	1500	29.
30.	Air Traffic Signal	6V	50W	T-8	D. C. Pref.	C-2V	1 3/8	3 1/8		50	30.
31.	Air Traffic Signal	110V	99W	T-8	D. C. Pref.	CC-13B	1 3/8	3 1/8	1800	50	31.
32.	Channel (Water)	[1]	6W (Green)	T-5	Min. Bipin			9			32.
33.	Channel (Water)	[1]	15W (Green)	T-8	Med. Bipin			18	900		33.
34.	Channel Threshold (Water)	[1]	6W (Gold)	T-5	Min. Bipin			9			34.
35.	Channel Threshold (Water)	[1]	15W (Gold)	T-8	Med. Bipin			18	375		35.

[1]Fluorescent lamp to be used with auxiliary of proper design.
[2]Vibration Service Lamp. Operating position base up or base down only.
[3]Under specified test conditions.
[4]Recommended for use on airports having non-scheduled operations.
[5]Recommended for use on airports having scheduled operations.
[6]Where necessary, 120- or 125-volt lamps are available.
[7]Nominal length.
[8]Air cooled high pressure mercury lamp to be used with auxiliary of proper design.

to restrict the design of new equipment. Their objective was, in the light of available knowledge, wherever possible to guide design toward the use of the best lamps for each service.

The subcommittee which drew up the tables is still active and plans to make revisions from time to time in keeping with new knowledge and advanced practices. Thus the lighting equipment design engineers can have at their fingertips information which represents the latest recommendations on the part of lamp and equipment engineers.

V. J. ROPER, *Chairman*

J. F. Angier	J. M. Roper
G. M. Kevern	R. A. Rugge
J. D. Hall	SAE Lamp Committee

The report of the above committee was circulated and approved through letter ballot by the Aviation Lighting Committee.

RALPH R. BRADY, *Chairman*
L. B. MOORE, *Vice-Chairman*
D. C. MILLER, *Secretary*

H. Ainsworth	James F. Angier
F. C. Ashe	A. L. Lewis
J. B. Bartow	R. E. Madigan
H. R. Blackwell	W. E. K. Middleton
R. C. Blatt	H. J. C. Pearson
Frank B. Brady	W. A. Pennow
F. C. Breckenridge	J. M. Roper
A. H. Clarke	V. J. Roper
G. K. Clement	R. A. Rugge
D. I. Coggins	J. Penn Rutherford
Roy E. Dahlin	L. C. Simpson
Wilbur T. Harding	Davis H. Tuck
John P. Hoxie	L. C. Vipond
F. B. Kemery	N. O. Weston
G. M. Kevern	

LAMPS FOR AIRCRAFT LIGHTING. IES-SAE RECOMMENDED PRACTICE
The lamps shown are those *recommended* for the service indicated. This list is not intended to be a catalog and, hence does not include many types of lamps now in use.

Line No.	Service	Circuit Volts	Lamp No.	Army-Navy Part No.	Amps, Watts, or Candles	Bulb	Base	Filament	Light Center Length (Inches)	Max. Overall Length (Inches)	Design Volts	Max. Amps at Design Volts		Rated Avg. Lab. Life (Hours)[4]	Approx. Weight Each (Pounds)	Line No.
1	Landing	6	4538		100W	PAR-46	So. Term.	C-6		3⅝	5.4			25	.92	1
2	Landing	12-16	4537		100W	PAR-46	So. Term.	C-6		3⅝	13.0			25	.92	2
3	Landing	12-16	4522		250W	PAR-46	So. Term.	C-2V		3⅝	13.0			25	.92	3
4	Landing	24-28	4523	AN3129-4523	250W	PAR-46	So. Term.	C-11		3⅝	28.0			25	.92	4
5	Landing	24-28	4560	AN3130-4560	600W	PAR-64	So. Term.	C-13		4	28.0			25	2.00	5
6	Taxiing	24-28	4570		150W	PAR-46	So. Term.	CC-6		4	28.0			300	.92	6
7	Position	6-8	87		15c	S-8	S. C. Bay.	C-2R	1⅛	2	6.75	2.04		300	.021	7
8	Position	6-8	1506[3]		24c	GG-10[3]	S. C. Index.	CC-6		2¼	6.4	3.48		300	.019	8
9	Position	12-16	93		15c	S-8	S. C. Bay.	C-2R	1⅛	2	12.8	1.15		500	.021	9
10	Position	12-16	1512[3]	AN3122-1514	24c	GG-10[3]	S. C. Index.	C-2R		2¼	12.8	1.6		300	.019	10
11	Position	12-16	1143		32c	RP-11	S. C. Bay.	C-2R	1¼	2⅝	12.5	2.13		400	.023	11
12	Position	12-16	1747	AN3133-1747	50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	12.5	3.6		300	.022	12
13	Position	24-28	1524[3]	AN3122-1524	24c	GG-10[3]	S. C. Index.	CC-6		2¼	28.0	0.83		300	.019	13
14	Position	24-28	315[7]		32c	S-8	S. C. Bay.	C-2V	1⅛	2	28.0	1.03		300	.021	14
15	Position	24-28	311	AN3133-311	50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	28.0	1.55		300	.021	15
16	Interior	6-8	63		3c	G-6	S. C. Bay.	C-2R	⅝	1½	7.0	0.73		1000	.012	16
17	Interior	6-8	81		6c	G-6	S. C. Bay.	C-2R	⅝	1½	6.5	1.14		500	.012	17
18	Interior	6-8	87		15c	S-8	S. C. Bay.	C-2R	1⅛	2	6.75	2.04		300	.021	18
19	Interior	6-8	1129		21c	S-8	S. C. Bay.	C-2V	1¼	2	6.4	2.91		200	.021	19
20	Interior	6-8	1725		50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	5.5	6.95		100	.022	20
21	Interior	12-16	77	AN3141-77	3c	G-5	S. C. Bay.	C-2V	⅛	1⅜	13.0	0.41		1000	.012	21
22	Interior	12-16	89	AN3131-89	6c	G-6	S. C. Bay.	C-2R	⅝	1½	13.0	0.63		750	.012	22
23	Interior	12-16	1141	AN3124-1141	21c	S-8	S. C. Bay.	C-2R	1¼	2	12.8	1.5		500	.021	23
24	Interior	12-16	1141SB[1]	AN3124-SB1141	21c	S-8	S. C. Bay.	C-2R	1¼	2	12.8	1.5		500	.021	24
25	Interior	12-16	1747	AN3133-1747	50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	12.5	3.6		300	.022	25
26	Interior	12-16	1747SB[1]	AN3133-SB1747	50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	12.5	3.6		300	.023	26
27	Interior	24-28	301	AN3141-301	3c	G-5	S. C. Bay.	C-2	⅛	1⅜	28.0	0.19		500	.012	27
28	Interior	24-28	302	AN3131-302	6c	G-6	S. C. Bay.	C-2	⅝	1½	28.0	0.34		500	.012	28
29	Interior	24-28	307	AN3124-307	21c	S-8	S. C. Bay.	C-2V	1¼	2	28.0	0.75		300	.021	29
30	Interior	24-28	307SB[1]	AN3124-SB307	21c	S-8	S. C. Bay.	C-2V	1¼	2	28.0	0.75		300	.021	30
31	Interior	24-28	311	AN3133-311	50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	28.0	1.55		300	.021	31
32	Interior	24-28	311SB[1]	AN3133-SB311	50c	S-11	S. C. Bay.	C-2V	1¾	2⅝	28.0	1.55		300	.022	32
33	Interior	24-28	1385[7]		20W	R-12[7]	S. C. Bay.	CC-8		2⅝	28.0	0.79		300	.026	33
34	Interior[5]				6W[7]	T-5	Min. Bipin			9						34
35	Interior[5]				8W[7]	T-5	Min. Bipin			12						35
36	Interior[5]				14W[7]	T-12	Med. Bipin			15						36
37	Interior[5]				15W[7]	T-8	Med. Bipin			18						37
38	Interior[5]				30W[7]	T-8	Med. Bipin			36						38
39	Indicator or Instrument	6	328	AN3140-328	20A	T-1¾	Mid. Flange	C-6		⅝	6.0	0.22		500	.0012	39
40		6-8	44		25A	T-3¼	Min. Bay.	C-2R		⅝	6.3	0.275		2000	.006	40
41		6-8	63		3c	G-6	S. C. Bay.	C-2R		⅝	7.0	0.73		1000	.012	41
42		6-8	81		6c	G-6	S. C. Bay.	C-2R		⅝	6.5	1.14		500	.012	42
43		14	330		28A	T-1¾	Mid. Flange	C-2V		⅝	14.0	0.09		350	.0012	43
44	Indicator or Instrument	12-16	77	AN3141-77	3c	G-5	S. C. Bay.	C-2V		⅛	13.0	0.41		1000	.012	44
45		12-16	89	AN3131-89	6c	G-6	S. C. Bay.	C-2R		⅝	13.0	0.63		750	.012	45
46		12-16	1816[3]	AN3123-1816	33A	T-3¼	Min. Bay.	C-2V		⅝	13.0	0.38		1000	.006	46
47	Instrument	12-16	F3RP12-560BL		3W	RP-12	D. C. Index.			2⅝	*			200	.026	47
48	Indicator or Instrument	24-28	327	AN3140-327	24A	T-1¾	Mid. Flange	C-2V		⅝	28.0	0.048		350	.0012	48
49		24-28	301	AN3141-301	3c	G-5	S. C. Bay.	C-2		⅛	28.0	0.19		500	.012	49
50		24-28	302	AN3131-302	6c	G-6	S. C. Bay.	C-2		⅝	28.0	0.34		500	.012	50
51		24-28	313[9]	AN3124-313	6c	T-3¼	Min. Bay.	C-2		⅝	28.0	0.19		500	.006	51
52	Instrument	24-28	F5000	AN3123-F5000	4W	RP-12	D. C. Index.			2⅝	*			200	.026	52
53	Instrument	24-28	F2T6-BL		2W	T-6	D. C. Index.			2⅝	*			200	.022	53
54	Signalling	12-16	4590	AN3126-4590	6.6A	PAR-36	So. Term.	50 C-8		2¾	13.0			50	.52	54
55	Signalling	24-28	4561	AN3126-4561	3.3A	PAR-36	So. Term.	40 C-8		2¾	28.0			50	.52	55

[1]Silvered Bowl.
[2]Reflectorized bulb.
[3]Recommended only for intermittent use.
[4]Under specified test conditions.
[5]For operation with resistance ballast on 12-16 volt D.C. circuits.
[6]For operation with resistance ballast on 24-28 volt D.C. circuits.
[7]For horizontal burning only.
[8]Fluorescent lamp to be used with auxiliary of proper design. Does not operate satisfactorily over the temperature range required for military aircraft.
[9]Soft white color.

TELECAST

LIGHTING NEWS OF CURRENT INTEREST

Summary of Action Taken at Council Executive Committee Meeting

The regular meeting of the Council Executive Committee was held at the Union League Club in Philadelphia March 8. Vice-President Walter Sturrock presided in the absence of President C. H. Goddard. Present also were: S. G. Hibben, Vice-President; E. M. Strong, Treasurer; A. H. Manwaring, General Secretary, A. D. Hinckley, Executive Secretary; C. L. Crouch Technical Director; G. Ross Henninger, Editor-in-Chief I.E.S. Publications; C. E. Ellis, Advertising and Promotion Manager; and F. R. Adair, Conrad F. Bond, R. M. Hoot, T. W. Lauer, and Fred M. Pyle.

Membership Statistics

Acting favorably on the recommendation of the Board of Examiners, the Committee elected to Member Emeritus grade, E. H. Hobbie, long a distinguished Member of I.E.S. and early member of Council.

The Board of Examiners, E. M. Fahey, Chairman, reported further on their election of 83 Associates and 3 Students, and recommended the election or transfer of 22 full Members. Favorable action on their report, together with other changes brings the membership figures to those shown in the following tabulation:

September 30, 1949		March 8, 1950
6883	Total Membership	7132
26	Members Emeritus	29*
44	Fellows	43
1521	Members	1587
5048	Associate Members	5181
244	Student Members	292

*Includes 6 Fellows of the Society.

The Executive Secretary presented a comparison of membership additions and losses including March actions between the first five months of 1948-49 and the first five months of 1949-50. He noted that the records in the two years were comparable with resignations to date running somewhat ahead of last year's record.

Sustaining Members

Two new Sustaining Members were elected, on the recommendation of George J. Taylor, Chairman. Added to the roster of Sustaining Members were:

Detroit Electrical Contractors Association
627-628 Hotel Book Cadillac
Detroit 26, Michigan
Official Representative—Carl J. Schoeninger

Tristate Electrical Supply Co., Inc.
38 S. Potomac Street
Hagerstown, Maryland
Official Representative—Robert A. Stott

A. H. Manwaring, General Secretary, reported the circulation to all Sustaining Members of the new Society Brochure together with his letter covering the report of the General Secretary for the previous fiscal year. He mentioned several appreciative replies from Sustaining Members.

Local Activities

S. G. Hibben, Chairman of the Local Activities Committee, reported considerable activity in two locations leading to the establishment of new chapters. The local representatives in Jackson, Mississippi (Daniel Charbonnet) and Toledo, Ohio (E. F. Schmidt) have active programs well underway in these locations. Mr. Hibben also reported extensive interest in possible Student Branches from a number of universities throughout the country.

A local activities program of special interest to Canadian members is planned in connection with the Canadian Regional Conference in Montreal, May 10, Mr. Hibben said.

Local Activities Conference June 5 in New York

A special conference for the interchange of ideas on operation methods between incoming and outgoing local officers has been called for June 6 in New York City. All 1950-51 Section and Chapter officers will be invited to meet with each other, as well as the outgoing officers, for a full-day conference on local activities. Officers attending this meeting in the past several years have found it an invaluable aid to their administration.

I.E.S. Research Fund Submits Annual Report

Personnel and organizational changes, and general research activity were reported by the I.E.S. Research Fund in its annual report for the year 1949. As covered in detail in the January issue of Illuminating Engineering (page 66) researches were reported to have progressed to the point where three completed and four progress reports have been made to the Research Executive Committee, and one has been processed and approved by the Trustees with recommendation for publication. Contracts for two more projects were reported to have been drawn up with still further proposals being studied.

Board of Trustees

Elections held December 7, 1949 for replacement for one expired term of the Board of Trustees resulted in the re-election for five more years of Anthony W. Deller. Mr. Deller has served continuously from the Fund's inception. During 1949 the following men served as members of the Board with the terms as shown:

Anthony W. Deller (re-elected for 5 more years)	To Oct. 20, 1949
Alfred H. Nicoll	To Oct. 20, 1950
J. W. Barker	To Oct. 20, 1951
A. F. Wakefield	To Oct. 20, 1952
Conrad Berens, M.D.	To Oct. 20, 1953
R. W. Staud	To Sept. 30, 1948
L. E. Tayler	To Sept. 30, 1950
C. H. Goddard	To Sept. 30, 1951

Research Executive Committee

In accordance with the provisions of the Trust Fund, action was taken by

the Trustees to fill vacancies in the Executive Committee caused by the expiration of the terms of two members. From the list of candidates presented by the Council of the Illuminating Engineering Society, two members were appointed, namely, R. M. Zabel and George R. Harrison (re-elected for a term of three years). The members of the committee and their terms are as follows:

Ward Harrison	To Oct. 20, 1950
Howard M. Sharp	To Oct. 20, 1950
J. O. Kraehenbuehl	To Oct. 20, 1951
Ralph M. Evans	To Oct. 20, 1951
George R. Harrison	To Oct. 21, 1952
R. M. Zabel	To Oct. 20, 1952

Officers of the Fund

By action of the Trustees at their meeting December 7, 1949, the following were elected to serve as officers of the Fund:

A. F. Wakefield, Chairman
A. H. Nicoll, Treasurer
C. L. Crouch, Secretary
Ward Harrison, Chairman

Southwestern Regional Conference in Dallas Outstanding Success

It must be true what they say about Texas. Anyway, when the I.E.S. members down there hold a conference, everything about it is big. Their papers sessions are of national interest. Their fun is *fun*. (And their girls are pretty —see photos.)

The two-day Conference at the Adolphus Hotel in Dallas, February 27-28 exemplifies this.

Planned Lighting Session

The Conference proper was preceded by a full-day planned lighting promotion session, for which C. A. Tatum, commercial manager of the Dallas Power & Light Co., served as Chairman. Some 110 people attended this session.

Herbert L. Nichols, Chairman of the Board for the Southwestern Public Service Co., Dallas, opened the session with the subject "Importance of Lighting Sales to the Utility Industry."

C. B. Barron, Gulf States Utilities Co. of Beaumont, Texas and Chairman of Region J Planned Lighting Promotion Committee, spoke on "The Edison Electric Institute Planned Lighting Program."

J. Mason Guillory, manager of the industrial and commercial division of the New Orleans Public Service Co., discussed "Commercial Planned Lighting Pays."

"Planned Lighting Promotion in a Large City" was covered by C. J. Blum, superintendent of residential and farm sales for the Houston Lighting and Power Co., while Dan Jones Castle of the Southwestern Public Service Co., Plainview, Texas discussed "Planned Lighting Promotion in Smaller Towns."

At the afternoon session on Monday, C. B. Barron served as Chairman introducing:

R. N. Hankings, vice-president of the Albert Sechrist Manufacturing Co., Denver, Colorado, on the subject "Slimline Sales, Past, Present and Future."

F. I. "Tug" Wilson of F. W. Wakefield Brass Co., Vermilion, Ohio, on "Planned Lighting Promotion for Schools and Offices." Mr. Wilson asserted, with reason, that Texas has done more for school lighting than any other state in the nation, especially praising the work in this field undertaken by the Texas State Health Department.

A "Round Table on Lighting Sales Planning" closed the meeting.

Monday's luncheon, speaker was I.E.S. President C. H. Goddard, who addressed the gathering, on the Society's relation to the lighting industry. The meeting was the Electric Club's regular luncheon with conference delegates attending as guests. Mr. Goddard stressed that the lighting industry has a big job ahead of it.

"We must co-ordinate our efforts to put over a planned lighting program for the nation," he asserted. "And that includes not only these engineers who are meeting here, but it must also be boosted by the manufacturers, salesmen, and the public itself." Mr. Goddard also praised the work of Texas on its school lighting research.

Technical Session

The technical program of the Southwestern Regional Conference assumed National Conference proportions in the importance of the papers, presented by specialists from all parts of the country.

Opening the program at the morning session, was Dr. M. H. Bigelow, Technical Director for the Plaskon Division of Libbey-Owens-Ford Glass Co., Toledo, Ohio. Author of *The Handbook on Plastics*, and long a distinguished expert in his field, Dr. Bigelow presented "The Use of Thermoset Plastics in Lighting."

Dr. O. L. Pierson, a leading plastics expert with Rohm and Haas Co., Philadelphia, Pa., also spoke on "Thermoplastic Materials in Lighting." Both

Sales promotional session of the Southwestern Regional Conference in Dallas, Texas. C. A. Tatum of the Dallas Power and Light Co. was chairman. More than 100 delegates attended this session.

A group of those attending the ranch style dinner and square dance given in honor of President and Mrs. Charles H. Goddard, at the Southwestern Regional Conference, Dallas.

speakers discussed the current trend in luminous plastic ceilings in industrial and commercial lighting.

Recent developments in fluorescent lighting was discussed by A. C. Barr of the General Electric Co., Nela Park, Cleveland, Ohio, in his papers "Color in Lighting," at the morning session, and "Fluorescent Lamp Development" in the afternoon.

"Designing Downlighting for Commercial Interiors" was presented by E. D. Altree, manager of the Engineering Dept. of Pittsburgh Reflector Co.

The closing presentation of the technical session was a discussion of "Best Southwestern Lighting Installations of 1949," by utility representatives.

Social Functions

The Southwestern Conference must be one of the higher highlights of an I.E.S. President's travels. He usually is presented with a ten-gallon Stetson and a Texas shirt which can only be described as terrific.

The President's Reception and "Banquet" in Dallas, followed this tradition, with a ranch style dinner and Texas square dance. More than 100 people attended the party.

In true Convention style, a complete program for both days of the Conference had been planned for the entertainment of visiting ladies, in addition to the ranch dance.

A special luncheon with style show was featured Tuesday noon, and other special events scheduled throughout their stay.

Acknowledgements

The hardworking members responsible for the success of the Conference were:

Officers

Floyd A. Covington, Regional Vice-President

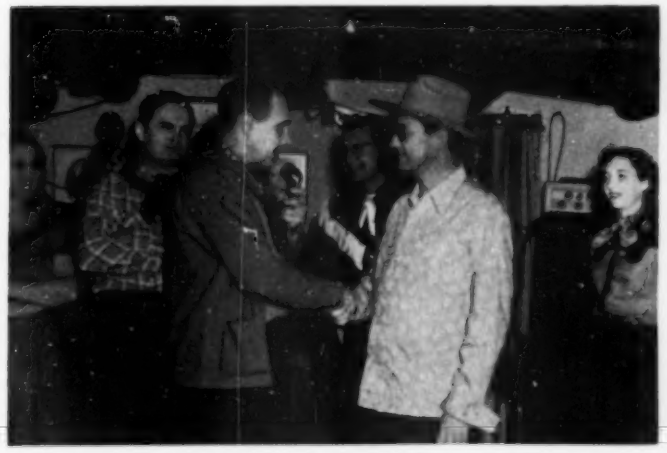
Harris L. Frazier, Chairman Alamo Chapter

Harry G. Hrivnatz, Chairman South Texas Chapter

Howard Ernst, Chairman Rocky Mountain Chapter

W. H. McAdams, Chairman Southwestern Section

At the Dallas Conference, left to right, Floyd Covington, Regional V-P; Pres. C. H. Goddard, and R. L. Biesele, Director of I.E.S.



President C. H. Goddard (right) is presented with the traditional ten-gallon hat and Texas shirt at the ranch style dinner and square dance featured by the Southwestern Regional Conference in Dallas. H. R. Heitzman, Southwestern Section Chairman (left) made the presentation. Ranch-style lighting also shown.

Conference Committee Chairmen

General Chairman—V. J. Graham

Co-Chairman—F. R. Army

Papers and Program—W. E. Folsom

Attendance Chairman—M. F. Baldwin

Hotel and Arrangements—W. T. Kimery

Entertainment—H. B. Sudekum

Finance—John G. Felton

Publicity—P. M. Rutherford, Jr.

Planned Lighting—C. B. Bacron

Atlanta Plays Host to Second Regional Conference

The second general conference of the Southern Region of I.E.S. was held at the Henry Grady Hotel in Atlanta, Georgia, Monday and Tuesday, March 6 and 7. The total registration of 211 persons included 139 I.E.S. members, and 72 men and women guests. Attendance came from all over the Region, as is indicated in the accompanying tabulation. The first Southern Regional Conference was held in Atlanta in May, 1944.

Two special presentations were made with fitting ceremony as part of the conference program. One of these was the Charter of the new I.E.S. Student Branch at Mississippi State College, which was presented by President C. H. Goddard to Kendall C. Dempsey, Chairman of the Branch.

The other award was a beautiful plaque established by the Georgia Section, to be awarded to the Section, Chapter or Branch in the Southern Region showing the highest attendance factor at a Southern Regional Conference. This factor is derived from the percentage of bona fide membership of the local unit in registered attendance and the distance in miles from the official home city to the conference city. The Mississippi State College Student Branch won the plaque and the corresponding privilege of being the first to have its name inscribed in one of the twelve places provided on the plaque.

At the opening session, Regional Vice-President Joe B. Browder presided. Georgia Section Chairman, Jack Murrah gave the address of welcome, tracing the history of the development of the Region from the chartering of the first chapter in August, 1949, to the present status of two Sections, four Chapters, a Student Branch, and a Residence Lighting Forum.

President Goddard addressed the group giving a very informative and thought-provoking outline of the Society's basic objectives, its present organizational structure, and its operational problems. He pointed out that about a thousand I.E.S. members are giving their time and effort in the furtherance of the Society's work, through the activities of the large family of technical and administrative committees.

At the second session, Monday afternoon, R. Brad Fogarty of the Georgia Section, and Chairman of the General Conference Committee, presided, Harold L. Salaun, Chairman of the New Orleans Section conducted the third session on Tuesday morning.

Arthur A. Brainerd, Chairman of the U. S. National Committee of the International Commission on Illumination was a featured speaker at the banquet gathering on Monday evening, speaking on the topic "Lighting — a World-Wide Interest" (see ILLUMINATING ENGINEERING, August, 1949, pages 463-4). Some 168 persons attended the reception and banquet, held in the Dixie Ballroom of the Henry Grady Hotel.

Hal M. Horton of the Georgia Section was toastmaster for the banquet, and added appreciably to its enlivenment with a parody take-off on the formal "Annual Progress Report" feature of the National Technical Conference Programs. Characteristic of his "exhibits" was a "flexible fluorescent lamp" capable of being tied in knots, or stretched to reduce it from standard to slimline proportions; also a trio of inter-linked circline fluorescent lamps "particularly suited to use in chain stores."

Another outstanding social affair on the program was an informal luncheon and floor show Monday noon in the Paradise Room of the hotel. A number of entertainment features were also specially planned for the women guests in attendance at the Conference. And those who got up early enough in the morning could — and some did — take part in the "Breakfast in Paradise" show of radio station WCON.

At the luncheon which brought the Conference to a close Tuesday afternoon, Harllee Branch, Jr., vice-president and general manager of the Georgia Power Co. addressed the Conference on the topic "Industry Looks to the South." Mr. Branch reviewed some of the factors which have contributed to the rapid and substantial growth of industry in the South that has characterized recent years. Regional Vice-President Browder presided at the luncheon.

Analysis of Atlanta Attendance

Section or Chapter	Attendance	Per Cent of Enrollment
Tennessee Valley	16	22
Miss. State College — Student Branch	11	44
Carolinas	11	15
New Orleans	7	7
Southeast Florida	4	6
Florida	3	3½
Georgia	97	64
Total number	139	
Guests	72	
Total attendance	211	

COMMITTEE PERSONNEL

A successful Conference means a lot of hard work by a lot of people. The people who did the job for the Southern Regional Conference in Atlanta are:

Steering Committee — R. Brad Fogarty (Chairman), Ruth Morris, George A. Love, Hugh Saussy.

Papers and Program — Jack H. Murrah (Chairman), Harold L. Salaun, E. E. Parks, A. C. Bergh, Jess D. Thomas, P. T. Tysinger, R. S. Wiseman.

Hotel — T. Taylor Penke (Chairman), Verlyn H. Branham, T. W. Haslam, Judd Lough, S. J. André.

Registration — J. T. Chambers (Chairman), Jack J. Burns, Walter C. Fink, Jr., Paul P. Harrison, Clarence D. Holland, Mrs. Ida Mae Hall, Mrs. Sara Alexander.

Entertainment — Cecil L. Cannon, Mrs. Cecil L. Cannon.

Finance — Herbert L. Reed (Chairman).

Publicity — Mrs. Rita Kuzell with the Publicity Chairmen of the Sections and Chapters of the Southern Region.

TECHNICAL PAPERS DIGESTED

The Technical Program of the Atlanta Conference embraced the following technical papers:

1. "Color — Its Applications in Canneries," by David C. White of the Florida Chapter.

2. "The Planned Lighting Program," by J. Mason Guillory, of the New Orleans Section.

3. "Prescribing for Comfortable Seeing in the Office," by Buford H. Martin of the Tennessee Valley Chapter.

4. "The Technique of Sports Lighting," by E. W. Michel of the Carolinas Chapter.

5. "Forty Years of Textile Lighting," by Frank E. Keener of the Georgia Section.

6. "Traffic Safety Lighting — Its Theory and Application," by R. S. Bostwick of the Southeast Florida Chapter.

7. "Architectural Lighting in the Home," by E. W. Commery of the Cleveland, Ohio Section, sponsored by the Atlanta Residence Lighting Forum.

Presentation of the Attendance Award at the Southern Regional Conference, I.E.S., Atlanta, Ga., March 7th, 1950. This trophy was given by the Georgia Section and will rotate among the winners at Regional Conferences for the next 12 years. It was won this year by the Mississippi State College Student Branch who had 40 percent of its membership present. Left to Right: Robert S. Wiseman, Faculty Advisor, Joe B. Browder, Regional Vice-President, and K. C. Dempsey, Chairman of the Student Branch.

Color in Canneries

Important advances and improvements in the handling and processing of food products have been made by the canning industry during the past three decades. Recently, the importance of good seeing conditions has been recognized as essential to the maintenance of sanitation standards and to quality control. Investigations of seeing conditions have disclosed that the lighting of sorting and canning belts for the selection of maturity grades was a problem of major importance in most canneries, especially where the degree of maturity in the fruit or vegetable product is an important factor in the quality of the product. For example, maturity grades of peaches are classified as fancy grade, choice grade, standard grade, etc.; these grades being determined by ripeness, size, and perfection of product; and the maturity of the product being judged primarily by its color, and sorted for quality on the basis of color comparison. As this maturity grading affects the farmer's payment for his product, the profit return to the cannery, and the quality of canned product purchased by the consumer, it is very important to the canning industry.

Dr. White discussed the problem of increasing the ease and accuracy of color sorting in the canning industry. The problem arose in connection with a research project sponsored by the National Canners Association and carried on at Stanford University 1946-49. Dr. White reported that the investigations have been conducted in three major parts:

1. Studies of the relation between the spectral reflectance properties of agricultural products and the degree of their maturity.

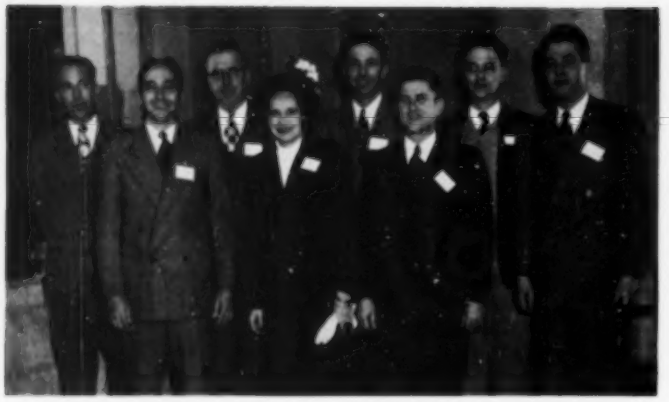
2. Studies of the spectral quality of light source best suited to color difference detection in fruits and vegetables.

3. Studies of the importance of the color of backgrounds and surrounds in the detection of color differences.

The studies mentioned in 1 and 2 have been conducted with many agricultural products; the studies reflected in item 3 have been limited to clingstone peaches, and have resulted in the establishment of the desired lighting conditions for accurate color grading of clingstone peaches, conditions sufficiently general that they may be extended to similar color-difference problems.

The spectral reflectance curves of some 14 fruits and vegetables were studied; all have shown interesting correspondence between maturity of product and reflectance over parts of the visible spectrum. For example, a typical set of curves for the several grades of clingstone peaches reveals, as a common characteristic, a decrease in reflectance at 675 millimicrons with decreases in maturity. Visual inspection of peaches, however, does not show large color differences between different degrees of maturity. The spectral curves of peaches emphasize the disadvantage of sorting peaches visually, as by far the greatest difference in reflectance occurs between maturity grades at 675 millimicrons, a quality of light to which the eye is relatively insensitive, yet visual sorting is done in the region between 500 and 620 millimicrons. At 675 millimicrons, there is a maximum difference in reflectance between fancy and sub-standard peaches

Presentation of Charter to Student Branch of Mississippi State College at the Southern Regional Conference, I.E.S., Atlanta, Ga. Left to right: K. C. Dempsey, Student Chairman, Robert S. Wiseman, Faculty Advisor, President Goddard.



Conference Committee Chairmen, Southern Regional Conference, I.E.S., Atlanta, Ga., March 6-7, 1950. Left to right: John T. Chambers, Registration; Joe B. Browder, Regional V.P.; T. Taylor Peake, Hotel; Mrs. Rita Kuzell, Publicity; Jack H. Murrah, Papers and Program; Cecil L. Cannon, Entertainment Herbert L. Reed, Finance; and R. Brad Fogarty, General Conference Committee.

of approximately 18 per cent, whereas between 500 and 620 millimicrons the maximum difference is only 7.5 per cent. This result indicates that photoelectric sorting of peaches should be investigated and may prove to be the final answer in this sorting problem.

Other tests carried on in connection with the visual sorting of peaches indicated conclusively that visual color comparisons are materially enhanced by the use of background and surround of approximately the average color of the product undergoing color-difference inspection.

In general, results of these investigations so far were reported as indicating most emphatically that "desired results cannot be obtained merely by hanging luminaires over the inspection areas to give a prescribed footcandle level of illumination; it is not enough to light an area, the area must be color conditioned as well." Color tests were reported as having been made at about 35 footcandles, and with color temperatures of both 6500° and 7500° Kelvin. "Theoretically natural north-sky daylight would be best."

Planned Lighting

In a manuscript prepared by J. Mason Guillory of the New Orleans Section and presented by J. M. Jennings of that Section, the Planned Lighting Program as carried out by the New Orleans Public Service Inc. was described, and illustrated by supplemental slides.

Emphasis was laid upon the five major components, or objectives, of Planned Lighting:

1. Planned Lighting must provide adequate illumination in the places where it is needed.

2. Planned Lighting must be efficient; minimum glare or light out of place, and no wasted wattage; quality of illumination or proper brightness level is not automatically attained when adequate levels of illumination are provided.

3. The planned lighting job must be tailored to the specific seeing task to be accomplished. This involves close cooperation between lighting engineer and architect.

4. Planned Lighting must be properly installed in accordance with plans and specifications. This involves the cooperation of the electrical contractor.

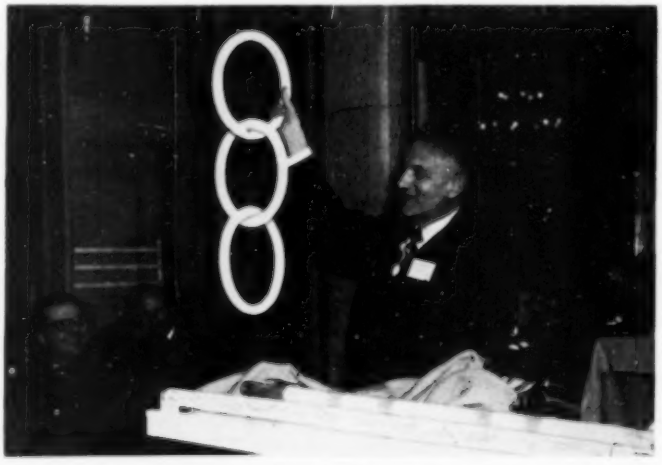
5. Planned Lighting is good lighting that is properly maintained by systematic and adequate servicing.

Office Lighting versus Seeing

Mr. Martin discussed the sometimes illusive relationship existing between the level of illumination and the seeing conditions in a business office. He pointed out that, in spite of all the literature that has been published on the subject, "higher footcandles still are all too often recommended as a cure for all seeing ills . . . still too many lighting installations are being sold and installed on the "more footcandle" basis only . . . many of these, while conforming to acceptable standards of *level* of illumination for the work to be performed in the area often are extremely uncomfortable to personnel and contribute to poor seeing conditions and needless fatigue. . . ." These results accrue from failure to take into consideration all of the environmental factors which directly affect seeing comfort, such as contrast, relative brightness levels within the field of vision, glare, etc.

Technique of Sports Lighting

The practices and procedures of lighting for sports and recreational purposes, as recommended in NEMA



Hal M. Horton, Vice-chairman of the Georgia Section presenting the facetious "Progress Report" at the banquet of the Southern Regional Conference, I.E.S. in Atlanta. Mr. Horton is showing three interlocked circline lamps which he says are "for use in chain stores and lend themselves readily to lamp group replacement programs." He also showed lamps made of "flexi-glass" and fluorescent lamps with "lukewarm cathodes, designed to replace all hot and cold cathode sources."

and I.E.S. publications were discussed by Mr. Michel. Mr. Michel reported that it was standard practice in his territory to design sports lighting installations to operate the incandescent lamps at 10 per cent over voltage, thus producing about 33 per cent more light with 16 per cent more power consumption, and to replace the lamps as a matter of routine after about a 200-hour playing season. Where playing seasons extend beyond 200 hours, he reported the use of only 5 per cent overvoltage.

There was considerable discussion between the proponents of two different schools of thought as to the overall best method of providing the 10 per cent overvoltage. One school of thought prefers the use of low voltage lamps to be operated at standard secondary distribution voltages, thus simplifying the installation. The other school of thought prefers the use of standard voltage lamps and the provision of the overvoltage by adjustable taps on the secondaries of the transformers serving the installation, in the belief that the user will more easily and more consistently be able to obtain standard voltage lamps than the special low voltage lamps.

Forty Years of Textile Lighting

Mr. Keener dramatized his subject by pointing out that "February 3, 1909 our first lighting recommendation was made and, as in practically every recommendation since that time, we were told our layout required too-high wattage, 0.3 watt per square foot. This lighting was for white cotton spinning . . . the original used 16-candlepower carbon lamps on 16-foot spacing in alternate alleys. We have calculated the lighting level at approximately 0.2 footcandles. Our new (1909) layout included 16-candlepower lamps staggered on 16-foot spacing in each alley, resulting in approximately 0.4 footcandles, or very extravagant lighting . . . during 1919 we replaced the 16-candlepower lamp with 75-watt tungsten lamps, in the same outlets, resulting in a lighting level of approximately 2 footcandles. . . . During 1927, we replaced the 75-watt tungsten lamps with 450-watt Cooper-Hewitt mercury lamps, on the same spacing, resulting in 15 footcandles . . . during 1949 we replaced the mercury lamps with two 100-watt fluorescent lamps, resulting in about 50 footcandles. . . ."

Mr. Keener strongly criticized "those elements in the lighting industry who seem to be more interested in selling equipment to a customer than in assuring that the customer will get a well-engineered lighting job designed to meet his needs to the best advantage." Mr. Keener stated that "if the following suggestions should be adopted by everyone in the lighting industry, we all would benefit and would make our work in the textile industry a work of romance rather than a selfish task, and we would be well repaid for our efforts to promote better production, resulting in higher wages and greater profits for the next forty years:

1. Make a careful study of customers' problems, and then make a recommendation for the best value to the customer.

2. Know why your recommendation is right, and why it has the greatest possible value to the customer, before you submit it to the customer.

3. After being sure your recommendation is to the best interests of your customer, never change the recommendation after it is submitted.

4. No product is perfect; be ready to point out its defects before the customer buys and later discovers the defects himself; build good will.

5. Remember that a fluorescent lamp is a mechanical device, and discuss the problems of proper maintenance with your customer before you secure the order . . . work out proper time tables for lamp replacements when the customer buys the installation . . . since it is easily possible for a fluorescent installation to depreciate 75 per cent from initial footcandles, without proper maintenance, this factor may create much ill will unless the customer is forewarned.

6. Never oversell your customer just because he trusts you.

7. Be an honest illuminating engineering salesman and not just an "order taker."

8. Help your competitor play the game fair by playing fair yourself.

9. Work toward building a lighting industry for America wherein a manufacturer who lowers the quality of his product for unfair price competition which gives the customer less value for his money will be forced to raise the quality, and value, of his product or get out of the I.E.S. Work to give our customers confidence in the I.E.S. emblem and to know that utmost confidence can be placed in anyone wearing this emblem. Work to build up to our level the competitor who is unfair, and not to lower ourselves to his level by trying to meet his unfair tactics. Always remember: "he profits most who serves best."

Traffic Safety Lighting

Mr. Bostwick developed the thesis that "the present need for the illuminating engineer is to consider and to develop for the good of the lighting profession his knowledge of the general public's reaction to good, bad, or indifferent street and highway lighting in order that the technical job may better satisfy those non-technical people who pay the bill. He offered the quotation from a prominent source that "the art (street lighting) has matured to the stage where the importance of efficiency as measured by laboratory instruments is losing ground in favor of effectiveness as evaluated by the physical and psychological gauge called 'comfortable seeing'."

Thus the engineer now must expand his technical knowledge to include a thorough study of the public reaction to modern street lighting. . . . It is a three-sided problem . . . the engineering side is well developed and supported by a wealth of technical literature published by I.E.S. and other sources . . . the other two sides — economics and human nature — are equally important to the structure. This relationship — engineering, economics, and human nature, has been humorously referred to as 'the infernal triangle' . . . to deal with the human side of the 'infernal triangle' becomes the street lighting engineer's major problem . . . the commonplace problem of engineering terminology also is a factor which adds its weight to general public difference . . . to picture the projected results of relighting a street in terms the layman can understand certainly challenges the ingenuity of the professional lighting engineer."

Lighting in the Home

An important highlight of the Atlanta Regional Conference was the highly instructive and stimulating talk given by E. W. Commery of the Cleveland, Ohio, Section, Chairman of the National Committee on Residence Lighting. Mr. Commery's assigned topic was "Architectural Lighting in the Home," which title sounds sophisticated and formal. But what he actually did was quietly to draw aside the cloak of unapproachability which has shrouded the down-to-earth and homely lighting problems of the average American residence-apartment or house — and present an engineering approach to the problem in simple every-day terms. The presentation was sponsored by the Residence Lighting Forum of the Georgia Section, and the audience of about a hundred contained between 25 and 30 women.

In speaking of the quantity and quality of light for the satisfactory performance of the visual tasks of the home, Mr. Commery referred to the tables of recommended levels of illumination and other technical and statis-

tical data, variously published by the I.E.S., *but*, in so doing, he warned strongly that "there is all too prevalent a tendency to give too much attention to the statistical or quantitative side of home lighting problems and not enough to the personal psychological factors — it takes a thoughtful combination of the two to produce a *satisfying* job at the levels of light needed for good seeing." Home lighting problems were categorized into fifteen "typical situations" ranging from the living room to the laundry and embracing such specifics as lighting for shaving, for milady's make-up, for reading in bed, and for fatigue-free television reception — each complete with dimensional sketches and installation photographs. Pin-up lamps of proper design were given an important place in home lighting, in the living room as well as in the bedroom. What Mr. Commery presented was in substance a preview of the current work of the I.E.S. committee on Residential Lighting in its lighting study practice looking toward a Recommended Practice.

LIGHTING CALENDAR

Society Events

April 6, 1950 — Meeting of I.E.S. Council, Edgewater Beach Hotel, Chicago, Ill.

May 11-12, 1950 — Canadian Regional Conference, Mt. Royal Hotel, Montreal, Que., Canada.

May 17-19, 1950 — Midwestern Regional Conference, Milwaukee, Wisconsin.

May 18-19, 1950 — East Central Regional Conference, Warwick Hotel, Philadelphia, Pa.

May 22-23, 1950 — Great Lakes Regional Conference, Buffalo, N. Y.

June 6, 1950—Local Activities Conference, for outgoing and incoming local officers of I.E.S., New York, N. Y.

June 7, 1950 — Meeting of I.E.S. National Council, New York, N. Y.

August 21-25, 1950 — Southern California National Technical Conference, Hotel Huntington, Pasadena, Calif.

Industry Events

April 4-6, 1950 — Edison Electric Institute, 16th Annual Sales Conference, Edgewater Beach Hotel, Chicago, Ill.

April 5, 6, 7, 1950 — 12th Annual Midwest Power Conference, Sherman Hotel, Chicago, Ill.

April 13-14, 1950 — The American Society of Mechanical Engineers, Spring Meeting, Hotel Statler, Washington, D. C.

April 17-18, 1950 — Annual Conference, Canadian Electrical Distributors Association, General Brock Hotel, Niagara Falls, Ont., Canada.

April 19-22, 1950 — The Electrochemical Society, 97th Convention, Statler Hotel, Cleveland, Ohio.

April 24-25, 1950 — Industrial Accident Prevention Association, Annual Convention, Royal York Hotel, Toronto, Canada.

May 10-12, 1950 — 1950 Commercial and Industrial Electrical Exhibit, E.M.R.A. Convention Hall, Detroit, Mich.

May 10-12, 1950—American Institute of Architects Convention, Washington, D. C.

May 15-18, 1950 — National Fire Protection Association, 54th Annual Meeting, Haddon Hall, Atlantic City, N. J.

May 29 - June 9, 1950 — Canadian International Trade Fair, Coliseum, Canadian National Exhibition Grounds, Toronto, Canada.

June 4-7, 1950 — The American Society of Refrigerating Engineers, 37th Spring Meeting, Muehlebach Hotel, Kansas City, Mo.

June 5-7, 1950 — Edison Electric Institute, 18th Annual Convention, Atlantic City, N. J.

June 12-16, 1950 — American Institute of Electrical Engineers, Summer General Meeting, Pasadena, Calif.

June 12-16, 1950 — National Association of Electrical Distributors, Atlantic City, N. J.

June 13-16, 1950 — Conference on Industrial Research, Columbia University, New York, N. Y.

June 15-19, 1950 — 60th Annual Meeting, Canadian Electrical Association, Murray Bay, Que., Canada.

June 26-30, 1950 — American Society for Testing Materials, 53rd Annual Meeting and 9th Exhibit of Testing Apparatus and Equipment, Atlantic City, N. J.

August 7-19, 1950 — First United States International Trade Fair, Chicago, Ill.

September 19-21, 1950 — The American Society of Mechanical Engineers, Fall Meeting, Hotel Sheraton, Worcester, Mass.

October 11-14, 1950 — International Association of Electrical Leagues, 15th Annual Conference, Copley Plaza, Boston, Mass.

October 16-20, 1950 — 38th National Safety Congress & Exposition of the National Safety Council, Chicago, Ill.

October 17-20, 1950 — National Electrical Contractors Association, Annual Convention, Hotel Biltmore, Los Angeles, Calif.

November 13-16, 1950 — National Electrical Manufacturers Association, Chalfonte-Haddon Hall, Atlantic City, N. J.

November 27-29, 1950 — American Standards Association, Annual Meeting, Waldorf-Astoria Hotel, New York, N. Y.

December 3-6, 1950 — The American Society of Refrigerating Engineers, 46th Annual Meeting, Hotel Commodore, New York, N. Y.

Plans Underway for East Central Conference

Advance registrations for the East Central Regional Conference May 18-19 in Philadelphia are being taken now by F. R. Adair, Chairman of the Registrations Committee. Reservations should be sent in immediately, addressed to him at P.O. Box 7663, Philadelphia 4, Pa.

An impressive program of technical papers has been arranged for this Conference, as well as entertainment features for the large attendance expected from the distaff side. Following the Address of Welcome by Joseph Schuchert, Regional Vice-President, East-Central Region and the Keynote Address by George E. Whitwell, Vice-President Philadelphia Electric Co., the timely subjects scheduled are:

Presentation of 1950 Planned Lighting Activity — Better Light Better Sight Bureau

Color and its Measurements by Dr. D. B. Judd, National Bureau of Standards

Lighting from Louverall Ceilings & Other Large Area Luminous Surfaces by Don P. Caverly and Robt. Wylie, Sylvania Electric Products Inc.

Lighting for Television by R. L. Zahour, Westinghouse Electric Corp.

Recent Developments in Light Sources by Willard C. Brown, Managing Engineer General Electric Company, Nela Park.

Open Forum Discussion led by Paul M. Hildebrand

Five Presentations developed from the contest conducted for "My Most Interesting Lighting Job".

Seminar on Light Feature of A.I.A. Convention

A Seminar on Light Session, impressive in its scope, will be an important feature of the American Institute of Architects three-day Convention scheduled for May 10 through 12 in Washington, D. C. The lighting symposium will be held May 11.

Details of the A.I.A. Seminar on Light designed as a cooperative discussion between architects and lighting engineers, were planned by C. L. Crouch, Technical Director of I.E.S., and Kenneth C. Welch, Grand Rapids, Michigan, who will also serve as moderator at the session.

Subjects to be presented at the seminar will be:

"Light and Vision," by C. L. Crouch, Technical Director of I.E.S. To be an instructive authentic presentation couched in terms designed for the layman rather than for the lighting theorist.

"Light Sources," by S. G. Hibben, Westinghouse Electric Corp. To dwell upon useful tools now available for the architect. Specifically to include discussion of new DR

Phosphors and the subject of color in lighting in general; also to embrace a summary review of trends of recent years in lighting costs.
"Daylighting," by R. L. Biesele, Jr., Professor of Electrical Engineering, Southern Methodist University, Dallas, Texas.
"Use of Color and Dramatic Light," by Stanley McCandless of Yale University.
"Application of Lighting to Practice," by Howard Sharp, noted consultant. It is understood that Mr. Sharp has of recent years been working very closely with architects and is in a position to "speak their language."

IT SEEMS TO ME

Bamberger's Store

To the Editor:

I was interested in seeing, on page 141 of the February 1950 ILLUMINATING ENGINEERING, the reproduction of the photographs of our lighting fixture, and the one showing the installation of these fixtures in Bamberger's. I was also interested to note, in the caption, that the fixture was developed as a result of consultations between the architects, store management and the lighting consultant.

First of all, it is difficult to understand why the manufacturer of the fixture was not given credit, and secondly, I must take exception to your statement that the fixture was designed in accordance with ideas suggested by the "lighting consultant." Mr. Den Braven's statement at the meeting should have dispelled such a notion. For the record, I would like to advise that the fixture as supplied by us was engineered and designed by us, and that the features, such as the removable reflector pans, optional spotlite equipment and convenience outlets, were included as a result of conferences between store management and ourselves. A fixture which had been made to the "lighting consultant's" specification was discarded in favor of our own.—LAWSON FULLERTON, *President, Fullerton Manufacturing Corp., South Norwalk, Conn.*

New Lamp Bulb Developed For Home Lighting

A new incandescent lamp of radically different design has been announced by General Electric Co., for use in the millions of two-to-five socket ceiling fixtures estimated still in use throughout the country.

Lighting performance of the lamp, available in the 50-watt size only, approximates the quality of lighting from a parchment-shaded lamp. When viewed from its recommended base-up position, the lamp resembles an inverted mushroom, 3½ inches in diameter. The lower portion of the bulb is covered with a parchment-color permanent enamel finish, with the upper portion frosted in the usual manner. Three concentric rings in the enamel and a clear spot at the bottom of the bulb, direct two-thirds of the light upward, and a small spot of down light for "sparkle."

Conceived by Dr. Matthew Luckiesh, recently retired director of the company's Lighting Research Laboratory at Nela Park, the lamp was developed over a period of several years under his guidance.

ABOUT PEOPLE

James A. Lang, Minneapolis Consulting Engineer, has recently purchased interest in the Scott Whitnah, Lang and Associates, Inc., and the company name has been changed to the Lang Engineering Company.

Thomas E. Roche, a charter member of the Twin City Section at its formation in 1937, has recently opened an office in Minneapolis, where he will do engineering consulting work.

Frederick S. Kinsey, eastern district manager of the Lamp Division of Westinghouse Electric Corp., has been elected president of the Electrical and Gas Association of New York. He succeeds **Harry C. Calahan**, vice-president of General Electric Supply Corp.

Robert W. Heller has been appointed manager of residential sales for Duquesne Light Co., Pittsburgh, Pa., succeeding T. O. McQuiston, who left to become sales manager of Metropolitan Edison Co., Reading, Pa.

Lewis P. Tabor, senior research engineer in the Franklin Institute Laboratories for Research and Development has just been elected chairman of the Institute's highly important Science and Arts Committee which is responsible for choosing the scientists to whom special Institute medals are awarded each year. Mr. Tabor will be the 66th chairman of this committee since it was originated in 1835. He replaces Laurence LePage of the Adrian Bauer Agency, who resigned to undertake other duties for the Institute.

Lawson Fullerton, president of Fullerton Manufacturing Corp., South Norwalk, Conn., has announced the appointment of the following representatives: **Russel Lighting** Equipment Co., Miami, for the state of Florida; **John Lowe**, Knoxville, Tenn., for eastern Tennessee; **W. M. Munding**, Memphis, covering western Tennessee, Arkansas, northern Mississippi and western Kentucky.

R. F. "Frank" Spangler has been appointed field service supervisor for the Pacific Coast, Seattle division of the Westinghouse Electric Corp., according to a recent announcement. Mr. Spangler, who assumed his new duties on March 1, replaces **W. F. Schanz** of Seattle, who moves to San Francisco as assistant to the service manager of the division.

NEW MEMBERS

BALTIMORE CHAPTER

Member:
Adams, C. T., Henry Adams, Inc., Baltimore, Md.

CAROLINAS CHAPTER

Members:
Cardo, J. J., Independent Electric Supply Co., Inc., Charlotte, N. C.
Southerlin, W. B., State Department of Education, Columbia, S. C.
Tindal, N. E., Union Supply & Electric Co., Charlotte, N. C.

Associate Members:
King, C. E., Tide Water Power Co., Wilmington, N. C.
Ligon, D. H., Ligon Electric Co., Hickory, N. C.

CAPITAL SECTION

Member:
Engle, C. R., Jr., General Engineering Associates, Washington, D. C.

CENTRAL NEW YORK CHAPTER

Associate Member:
Hughes, J. J., Hughes Lighting Studio, Syracuse, N. Y.

CHICAGO SECTION

Associate Members:
Brown, J. W., Central Illinois Light Co., Peoria, Ill.
Feldkamp, G. H., Crescent Electric Supply Co., Peoria, Ill.
Garrels, W. H., Commonwealth Edison Co., Chicago, Ill.
Kruse, George, Kruse Electric Co., Chicago, Ill.

Silverman, Harold, All-Bright Electric Products Co., Chicago, Ill.

CLEVELAND SECTION

Member:
Banahan, L. O., Ohio Edison Co., Akron, Ohio

Associate Members:
Haase, R. H., General Electric Co., Nela Park, Cleveland, Ohio
Kosker, E. M., General Electric Co., Nela Park, Cleveland, Ohio
Raymond, R. E., Westinghouse Electric Corp., Cleveland, Ohio
Seely, D. E., Westinghouse Electric Corp., Cleveland, Ohio
Young, W. C., Westinghouse Electric Corp., Cleveland, Ohio
Zimmerman, R. G., Ohio Edison Co., Youngstown, Ohio

Student Member:
Burgener, R. C., Case Institute of Technology, Cleveland, Ohio

CONNECTICUT SECTION

Associate Member:
Sohn, H. B., Jr., The Miller Co., Meriden, Conn.

CORNHUSKER CHAPTER

Member:
Haskell, L. V., Orchard Wilhelm Co., Omaha, Neb.

Associate Members:
Kris, R. L., Kris-Davis Co., Grand Island, Neb.
Randall, H. W., Nebraska Retail Hardware Association, Lincoln, Neb.

FORMOSA NON-SECTION

Associate Members:
Bezzi, C., S. An. Costruzioni Elettrotecniche Carlo Bezzi, Via Felice Poggi 14/24, Milano, Italy
Brittain, J. H., Lewers & Cooke, Ltd., P.O. Box 2930, 174 King, Honolulu, Hawaii
Petersen, Sven Hyr, c/o Esper Clemmensen, St. Kongensgade 36-38, Copenhagen K, Denmark
Sirry, Baher, #21 Ahram St., Guiza, Egypt
Spaens, Ch. Philips S. A. Belge, 37 rue d'Anderlecht, Brussels, Belgium

GEORGIA SECTION

Associate Members:
Barr, R. D., Westinghouse Electric Corp., Chamblee, Ga.
Miller, G. E., Pittsburgh Corning Corp., Pittsburgh, Pa.

HEART OF AMERICA SECTION

Associate Members:
Berry, M. K., American Structural Products Co., Kansas City, Mo.
Fleming, B. J., Jr., Fleming & Co., Kansas City, Mo.
Massaglia, P. E. C., 612 Temple Bldg., Kansas City, Mo.

INDIANA CHAPTER

Associate Members:
Burleson, R. L., Indianapolis Power & Light Co., Indianapolis, Ind.
Wilson, T. D., F. W. Wakefield Brass Co., Indianapolis, Ind.

IOWA SECTION

Associate Members:
Hoover, O. H., Electrical League of Des Moines, Des Moines, Iowa
Lamprecht, L. J., Osage Municipal Light & Power Co., Osage, Iowa

Student Member:
Skiles, P. S., Iowa State College, Ames, Iowa

MICHIGAN SECTION

Member:
Fairchild, Edward L., Prof., Wayne University, College of Engineering, Detroit, Mich.

Associate Members:
McDaniel, H. C., Westinghouse Electric Supply Co., Flint, Mich.
Tousey, R. M., The Detroit Edison Co., Detroit, Mich.

MONTREAL SECTION

Members:
Hendershot, R. E., Canadian Westinghouse Co., Ltd., Montreal, Que., Canada
O'Keefe, W. B., Sylvania Electric (Canada) Ltd., Drummondville, Que., Canada

Associate Members:
Knowlton, J. P., Brouillette Sigus, Montreal, Que., Canada
Nobbs, F. J., 1340 Union Ave., Montreal, Que., Canada

MOTHER LODE CHAPTER

Associate Members:
Crum, F. H., Wismer & Becker, Sacramento, Calif.
Mohr, R. A., E. I. du Pont de Nemours & Co., Inc., Sacramento, Calif.
Rosenberg, E. C., Pacific Gas & Electric Co., Sacramento, Calif.

NEW ENGLAND SECTION

Members:
Elliott, C. L., Henry L. Wolfers, Inc., Boston, Mass.
Klopot, H. A., 116 Newbury St., Boston, Mass.

Associate Members:
Hudson, H. E., Spero Electric Corp., Boston, Mass.
Riga, H. B., Riga Electrical Corp., Springfield, Mass.
White, G. W., Eastern Fixture Co., Boston, Mass.

NEW ORLEANS SECTION

Members:
Davis, B. M., Mississippi Power & Light Co., Jackson, Miss.
Chilton, H. R., Pittsburgh Reflector Co., Jackson, Miss.
Smith, D. T., P.O. Box 2574, Jackson 117, Miss.

Associate Members:
Ammons, S. C., Power Electric Co., P.O. Box 267, Jackson, Miss.
Briggs, R. E., Mallett & Associates, Jackson, Miss.
Crockett, W. R., Power Electric Co., P.O. Box 267, Jackson, Miss.
Drane, Becker, Gulf Sales Agency, New Orleans, La.
Fry, F. S., Graybar Electric Co., Inc., Jackson, Miss.
Guess, E. B., Mississippi Power & Light Co., McComb, Miss.
Irby, P. E., Stuart C. Irby Co., Jackson, Miss.
Pray, H. Q., Mississippi Power & Light Co., Jackson, Miss.
Smith, L. H., Mississippi Power & Light Co., Jackson, Miss.
Tyson, W. L., Jr., Southern Engineering & Electric Co., Jackson, Miss.
Walters, A. H., Mississippi Power & Light Co., Jackson, Miss.

Student Member:
Lipsey, J. E., Mississippi State College, State College, Miss.

NEW YORK SECTION

Member Emeritus:
Hobbie, Edward H., 121 Greenwood Ave., Madison, N. J.

Members:
Krueger, R. S., National Society for the Prevention of Blindness, New York, N. Y.
Lindholm, Paul, Western Electric Co., Kearny, N. J.

Associate Member:
Miller, Gladys, 535 Fifth Ave., New York, N. Y.

NORTHERN CALIFORNIA SECTION

Associate Members:
Congdon, G. E., Westinghouse Lamp Division, San Francisco, Calif.
Franks, H. S., 1180 Harker Ave., Palo Alto, Calif.
Kosman, Milton, Leader Electric-Western, Oakland, Calif.

OREGON SECTION

Associate Member:
Roy, R. R., Dr., 318 S. W. Alder St., Portland, Ore.

PHILADELPHIA SECTION

Member:
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These new fluorescent lampholders are designed primarily for use with T-12 (1½") Slimline lamps, but may be used for other sizes of slimline lamps.

Spring actuated plungers operate smoothly in guides and assure good electrical contact between the lamp pin and the lampholder contact.

Shock and vibration cannot displace the lamps.

The one piece steel covers are riveted to the steel back plates which are integral with the mounting brackets assuring rigid construction and providing a secure means of mounting. The covers, back plates and mounting brackets are baked white enamel.

The ribbed design of the plungers in device No. 4362 serves as a guide for lamp pin insertion.

These devices are provided with ¼" lay stranding wire leads which simplifies wiring (eliminates dipping or twisting of wire ends).

No. 4361—For low voltage primary, 660 Watts 250 Volts, equipped with two twelve inch white leads of No. 18 stranded, 1/32" insulation, 1000 Volt, 80°C. thermoplastic wire.

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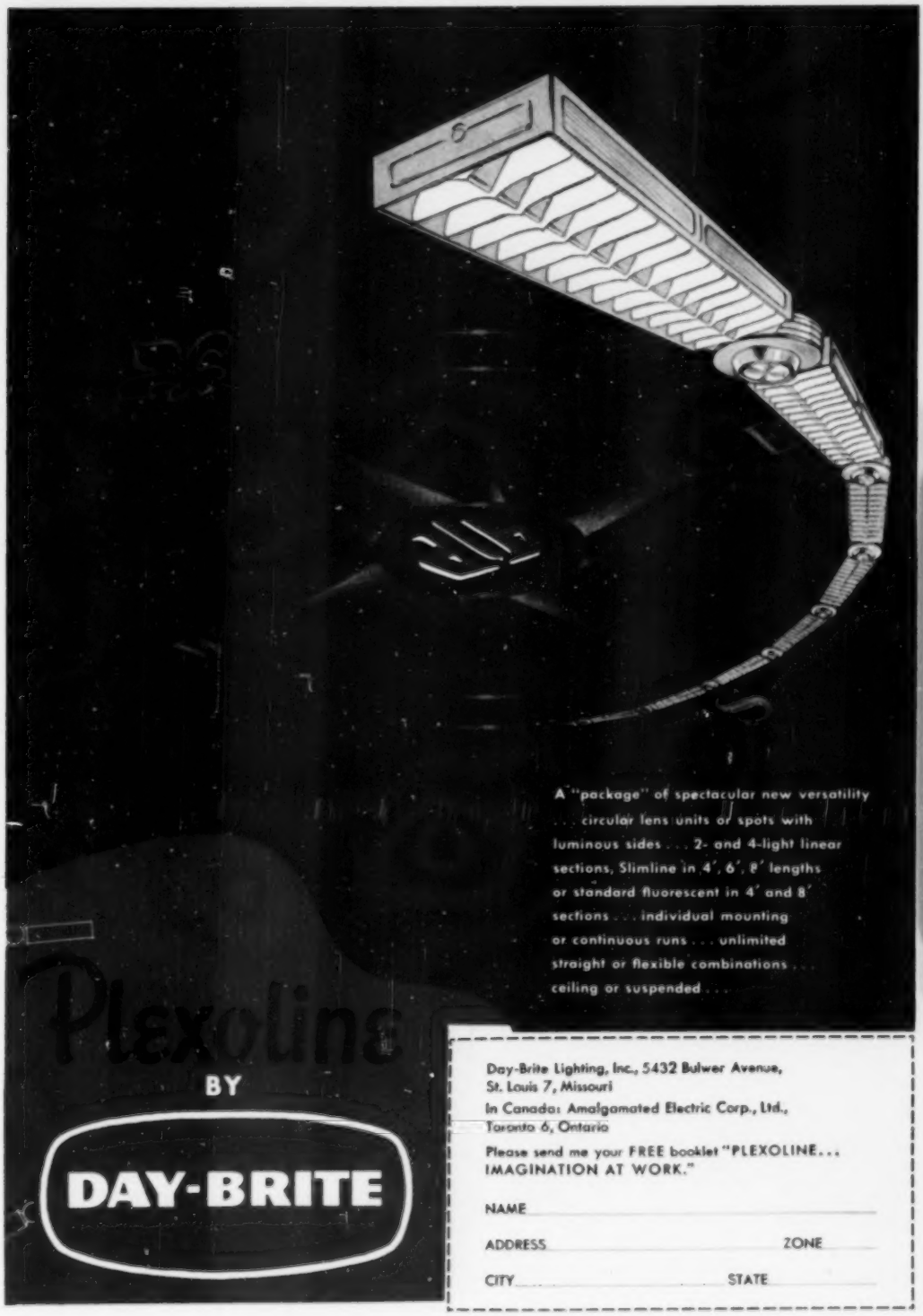
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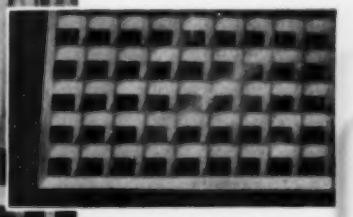

Close-up of FOTA-LITE showing how louvers penetrate full thickness of glass.

Like the Glow from the Northern Sky

Corning FOTA-LITE provides uniform brightness and control from both fluorescent or incandescent light sources

In the taste-testing kitchen of Kraft Foods Company, foods are appraised and arranged for color photography and advertising art. A high level of illumination plus exceptional brightness control was desired. A combination of incandescent and fluorescent were found desirable for delicate color control.

To blend the external appearance of both luminaires and use the most efficient and effective material, Corning FOTA-LITE glass was selected. The choice of FOTA-LITE gave excellent footcandle and brightness values. Comparative brightness readings *proved* that FOTA-LITE produced lower values than louvered fixtures or several other types of glass panels in the 45° to horizontal zone. It brought out color contrast with clarity and reality.

FOTA-LITE *is* a remarkable new lighting glass. Diffusing louvers are transmitted into the full thickness of glass by a photographic process. They never lose efficiency for the image is permanent. Light directed vertically remains unrestricted while the diffusing louvers intercept and eliminate glare at the 45° cut-off.

FOTA-LITE permits dust-tight fixture construction. Maintenance is no problem since only a single flat surface need be cleaned. There is almost no limit to its application as it may be used in recessed or pendant lighting fixtures, continuous row or complete luminous ceilings. You can evaluate it best by sending for a sample. Use form below.

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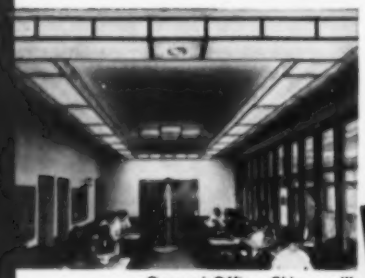

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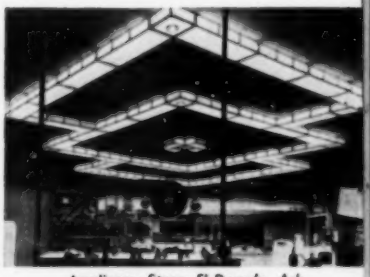

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module delivers 20% MORE LIGHT

Proved in actual use—MODULE delivers 20% EXTRA light per unit! Yes—the MODULE translucent plastic molded louver passes 20% MORE LIGHT. This means more light per dollar—fewer fixtures required to meet footcandle specifications. This means *more* light, *better* light at no more than the cost of ordinary fixtures.

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Here is instant starting for standard fluorescent lamps in residential-type fixtures. And it is accomplished merely by using a unique new ballast. With General Electric's revolutionary "trigger-start" ballast, any standard 20-watt lamp or any standard 32-watt Circline lamp starts with a flick of the switch.

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This label on a fixture carton, or the familiar G-E ballast tag on a fixture, is your assurance of fine ballast performance. Buy—when you see the G-E ballast label or tag.

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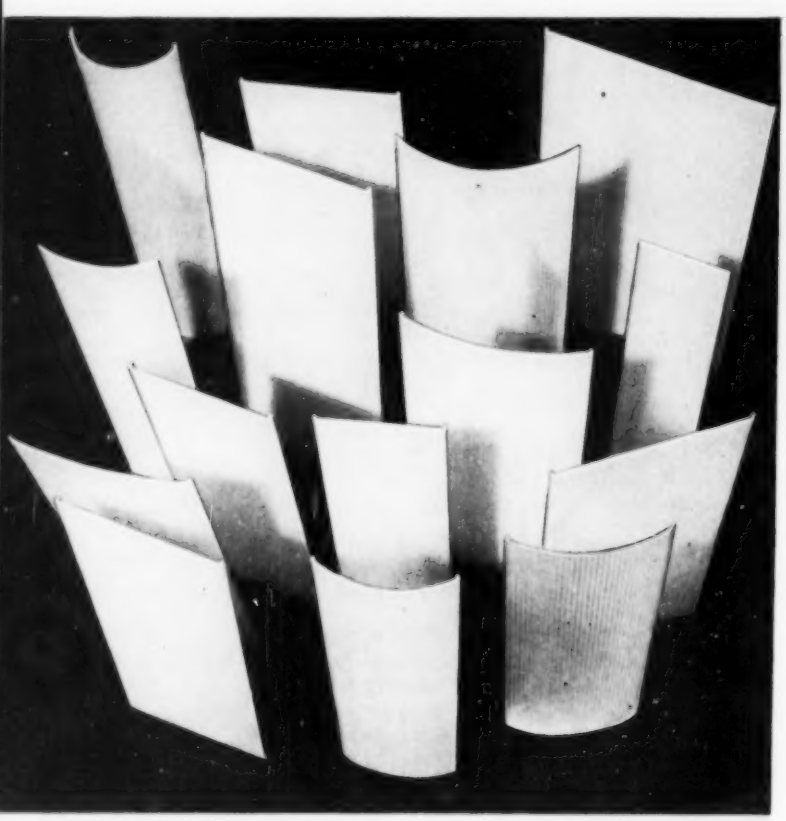

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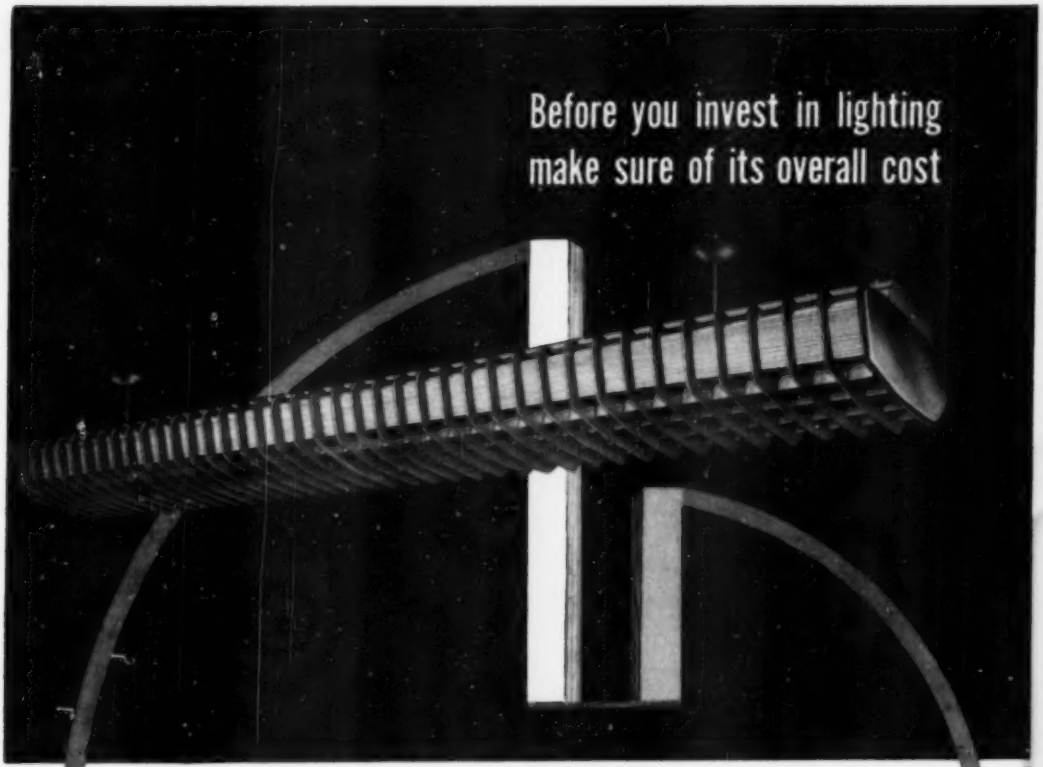

Miller "SERIES-LOUVER" luminaires for general line and slimline fluorescent lamps set a new high in lighting. Ideal for stores, offices and general commercial interiors.

OVERALL cost is equipment cost, *plus* cost of installation and maintenance. Built into all Miller lighting equipment are construction features that simplify installation and maintenance, and make for LOW OVERALL COST. When you add to this, fine illumination performance and pleasing appearance, you have the reason why Miller lighting equipment is your best investment in lighting. It is built on our 8-Point Standard of Quality Construction, and strict adherence to our 106-year tradition of pioneering in GOOD LIGHTING AT LOW OVERALL COST. Whatever your lighting requirements, you can light with confidence the proven Miller way. Miller field engineers and distributors are conveniently located. Write for Miller "SERIES-LOUVER" catalog.

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Recent improvements in Westinghouse Slimline Lamps give you these important advantages:

1. Brightness from end to end. The newly designed Westinghouse electrode . . . using zirconium . . . is short and squat. It casts no end shadows so lamps are bright through the entire length.

2. No starting stripe. An invisible coating of silicon takes the place of the customary opaque starting stripe. Thus installations look better.

3. Six hundred milliamperes loading for higher brightness where you want it. Because of superior cathode design and other improvements in manufacture, all Westinghouse T12 ($1\frac{1}{2}$" diameter) Slimline Lamps can be operated at 600 milliamperes if desired. At this loading the light output is increased about 20% over the standard 400 milliamperes rating. This flexibility enables you to plan more efficient lighting arrangements.

For complete technical data write: Lamp Division, Westinghouse Electric Corp., Bloomfield, N. J.

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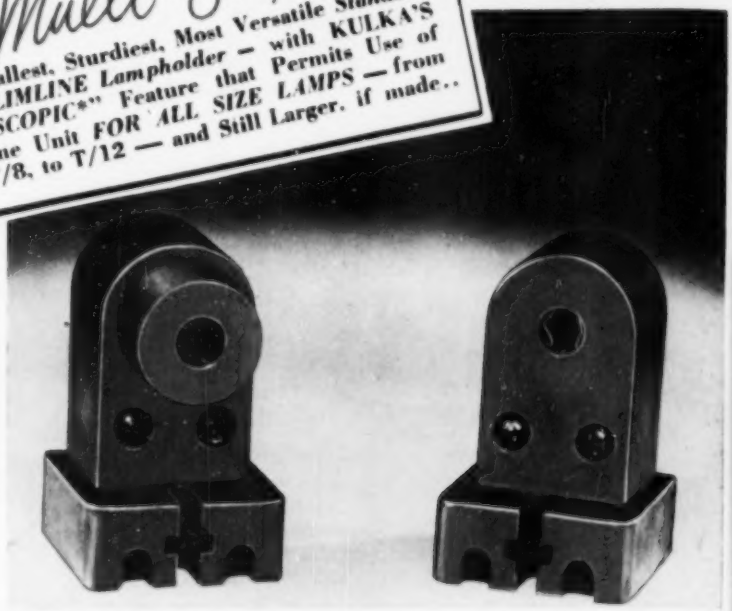
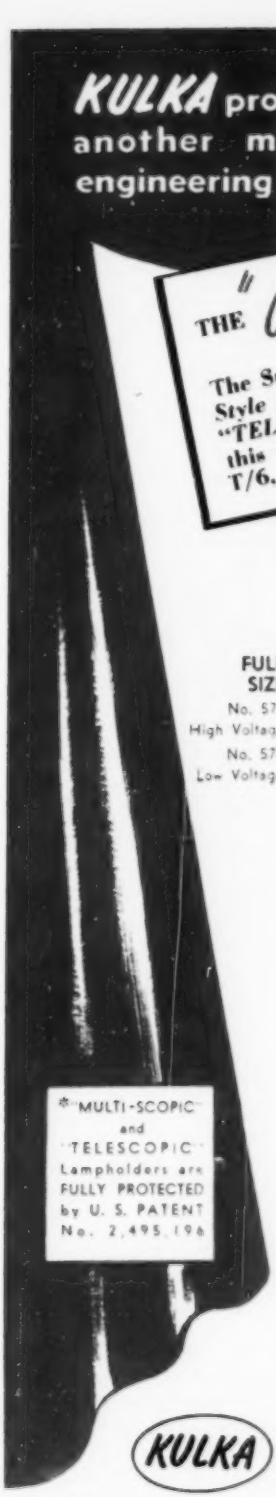
The Smallest, Sturdiest, Most Versatile Standard Style SLIMLINE Lampholder — with KULKA'S "TELESCOPIC"* Feature that Permits Use of this One Unit FOR ALL SIZE LAMPS — from T/6, T/8, to T/12 — and Still Larger, if made..



FULL SIZE
No. 575
High Voltage
No. 576
Low Voltage



* MULTI-SCOPIC and TELESCOPIC Lampholders are FULLY PROTECTED by U. S. PATENT No. 2,495,196

ONCE again Kulka leads the way — with an original and revolutionary SLIMLINE lampholder — the "MULTI-SCOPIC".*

Aptly named for its many uses, the "MULTI-SCOPIC"* combines the standard, single-screw mounting, bi-pin type, with the unique "TELESCOPIC"* holder we recently introduced.

The amazing feature of the "MULTI-SCOPIC"* is that despite its small, compact size it WILL TAKE ALL SIZE LAMPS — T/6, T/8, T/12 — and still larger, if they should be made.

Holders are of white Urea — a thermosetting plastic of high dielectric and tensile strength. Mounting portion is dimensionally the same as the standard type. Has front recess for a square nut, and also screw terminals staked and backed for easy wiring.

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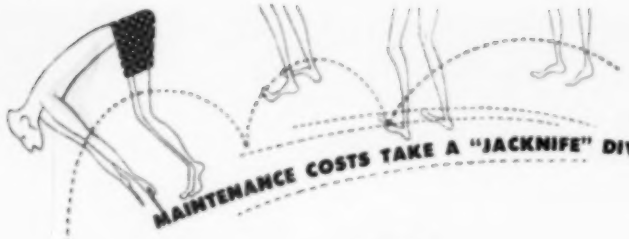

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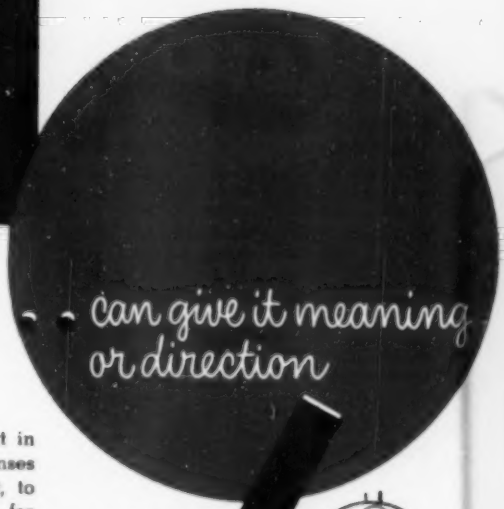

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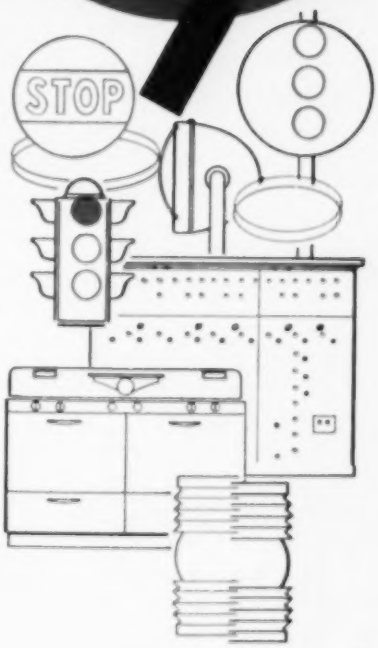

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GLASS
for lighting

Dunbar, America's most versatile glass plant, offers you 38 years of glass making know-how.

Complete (1) molding, (2) decorating and (3) cutting facilities all in one location provide efficient, economical production and rapid service.

Let us quote on your special shapes. Or, possibly one of our many stock blanks will save you money and time.

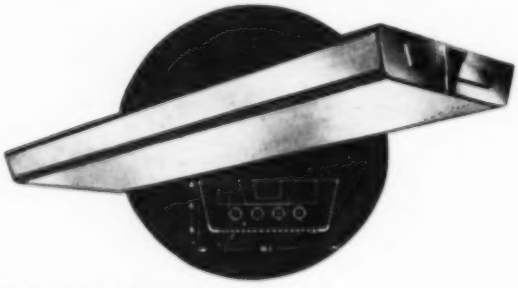
Write for catalogues on Dunbar "Lighting Glassware" and "Dunbar Glass Cylinders". Address Box 24.

DUNBAR

Dunbar Glass Corporation

DUNBAR, WEST VIRGINIA

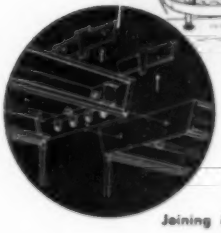
NEW YORK-CHICAGO-CLEVELAND-LOS ANGELES



We're all up in the air over this new design for better lighting

Simplicity of line and detail, combined with high light output and low surface brightness, are the primary features of the new **HG1040 SERIES** Designed to meet the higher standards of contemporary architecture, these units employ hinged shielding elements that allow easy lamp removal and maintenance. Specially constructed mounting devices facilitate installation. These units are available in 2, 3, and 4-lamp types in 48" single and bi-pin lamps and in 200, 300 and 430MA slimline. For further information on these units, please write...

One Man Hook-On Hanger For Suspended Mounting



Joining in continuous run

SUNBEAM LIGHTING COMPANY manufacturers of **BFK** lighting fixtures

777 EAST 14TH PLACE LOS ANGELES 21, CALIF.

how GOOD can PLANNED LIGHTING be without good equipment?

THE answer is – no better than a building plan without good building material. There is no dodging the fact that Good Equipment is the BASIC factor in a GOOD LIGHTING PLAN. It is the lighting units, the lampholders, the ballasts, the reflector, etc., which MAKE or BREAK the final results, in terms of sustained lighting efficiency, low-cost maintenance and dependable operation.

That's why, no matter how good the Lighting Plan, the results may be disappointing unless the plan includes GOOD EQUIPMENT.

the PUBLIC must be BETTER INFORMED on the importance of GOOD lighting equipment

As an industry, and as individual business men, we fail in selling PLANNED LIGHTING when we do not sell the importance of GOOD EQUIPMENT at the same time. It is our obligation that we keep faith with our customers by giving them the UNVARNISHED FACTS about the DIFFERENCE between GOOD and INFERIOR or SUBSTANDARD EQUIPMENT in terms of the factors listed below.

The buyer is entitled to KNOW these facts and to be TOLD and SHOWN that there are POSITIVE PROTECTIONS provided by the lighting industry, which assure him that the equipment he buys is in the GOOD EQUIPMENT BRACKET . . . the QUALITY BRACKET. *Proof of Quality* in lighting equipment is MADE EASY through such proof elements as:

CERTIFIED BALLAST LABEL

RLM LABEL

UNDERWRITERS' LABORATORIES LABEL

ELECTRICAL TESTING LABORATORY TESTS

These provide the buyer not only with the assurance that MINIMUM STANDARDS for performance have been met, but also that UNIFORM QUALITY is continuously maintained from one piece of equipment to the other.

FREE Booklet . . . The RLM Standards Institute has published a booklet containing the detail of each specification for each type of lighting unit for which RLM Standards have been established, as well as a complete summary of the IMPORTANCE OF THE LABEL in terms of CUSTOMER BENEFITS.

How the RLM Label provides assurance that the equipment is of uniformly high quality is shown through an outline of the RLM CONFORMANCE PROGRAM. Under this program, the Electrical Testing Laboratories make periodic tests of samples obtained from factory or market place to make sure that all equipment bearing the RLM Label consistently and continuously adheres to RLM Standards.

Make the RLM BOOKLET a part of every Planned LIGHTING PROPOSAL! . . . Write to the RLM Standards Institute for your COMPLIMENTARY COPY (or copies) of the RLM SPECIFICATION BOOKLET *today*. Plan to attach a copy to every PLANNED LIGHTING proposal you submit . . . let it help you point out to your customers that GOOD EQUIPMENT IS BASIC to GOOD PLANNED LIGHTING.

the PUBLIC is entitled to KNOW these FACTS about GOOD LIGHTING EQUIPMENT

CONSTRUCTION: Good Lighting Equipment features structurally sound fabrication and heavy steels for maximum resistance to sag, distortion and breakage.

FINISH: Good Lighting Equipment features reflector finishes that insure your getting all the light you pay for . . . this year and ten years from now! That is why good equipment so overwhelmingly features PORCELAIN ENAMEL—the one and only commercially available finish that cannot deteriorate or corrode, regardless of the industrial atmosphere. Additional advantages of Porcelain Enamel are (1) that it is the only finish whose original efficiency can be sustained year after year by simply washing it with soap and water, and (2) that it is UNSURPASSED as a reflecting surface, because it ideally combines a high reflection factor with a high diffusion factor, insuring high light output with a minimum of glare.

REFLECTOR DESIGN: Good Lighting Equipment insures good lighting through reflector design that conforms to the most accepted principles of Illuminating Engineering. Such design protects the workers' eyes while delivering, not only the *most light* per dollar, but also the *required quality of light* for the individual Seeing Task.

SOCKETS, STARTERS, LAMPHOLDERS: Good Lighting Equipment features ruggedly constructed parts that withstand years of use and embody special design which facilitates quick, money-saving maintenance and low-cost operation.

BALLASTS: Good Lighting Equipment insures you against trouble by employing only the highest quality certified ballasts. Ballasts last longer because sound electrical and mechanical design prevents high temperature ballast operations. Lamps last longer because certified ballasts supply proper starting current and maintain proper operating watts to the lamp. Present wiring capacity is used most efficiently by the high power factor of quality ballasts.

This Advertisement is published in the interest of the Entire Lighting Industry by

RLM STANDARDS INSTITUTE

The letters RLM stand for Reflector and Lighting Equipment Manufacturers

R-3487

RLM STANDARDS INSTITUTE, SUITE 823, 326 W. MADISON ST., CHICAGO 6, ILL.

This Above All–

SYLVANIA "FLEXI-MODULE"

A soft daylight effect of approximately 75 foot-candles covers the entire sales area of the Herpolsheimer Store. Note how the unobtrusive "Flexi-Module" Ceiling appears smooth and uniform in texture.

Miracles in lighting economy as well as efficiency are coming to pass with the Sylvania "Flexi-Module" System.

This modern system now opens new vistas in lighting design and beauty. It also results in lower building costs, lower maintenance costs . . . and greater flexibility than conventional lighting systems.

Reasons for low cost

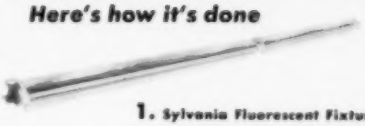
You save building costs with the "Flexi-Module" system because there's no need for expensive, buried-in-concrete construction. All air-conditioning ducts, utility cables and pipes are hidden between the subceiling formed by the louvers and the original ceiling.

Maintenance costs are low because the non-static aluminum grids prevent dust collection. In addition, the panels are coated with a special finish that does not finger mark and has an extremely low specularity . . . eliminates the need for repainting.

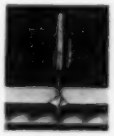
Furthermore, the extreme flexibility of this modern lighting system enables you to introduce interesting color patterns. And, these patterns can be changed from time to time . . . without the heavy expense of structural alterations.

Let us tell you more about the great possibilities that "Flexi-Module" lighting offers you and your customers. For complete information on the Sylvania "Flexi-Module" Lighting System, write *Advertising Dept. L-2904, 500 Fifth Ave., New York 18, N. Y.*

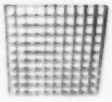
Here's how it's done



1. Sylvania Fluorescent Fixtures are first mounted on the original ceiling. Easily relocated. Easily serviced. Each unit can be wired for individual control.



2. Adjustable Hanger Straps and "Star" suspension units interlock adjoining grid sections. All leveling is done from below.



3. Non-static Aluminum Grids need no dusting or painting. Easy to handle. Beautiful to see.

SYLVANIA ELECTRIC

FLUORESCENT LAMPS, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; PHOTOLAMPS; TELEVISION SETS